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CTR-VDL-007

ENGINEERING TESTS ON BRE-LEYLAND RAILBUS

W.J. Watson

Prepared for
Transportation Development Centre
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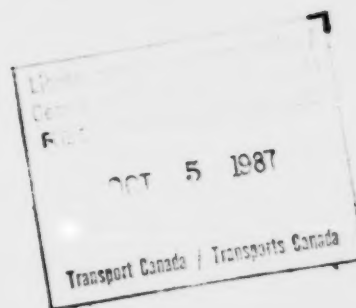
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ENGINEERING TESTS ON BRE-LEYLAND RAILBUS

W.J. Watson
Vehicle Dynamics Laboratory
Division of Mechanical Engineering
National Research Council of Canada

April 1986



Prepared for

Transport Canada
Transportation Development Centre

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Un sommaire en français de ce rapport est inclus avant la table des matières.

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17. Abstract This report documents a series of road and engineering tests carried out on the BRE-Leyland 141 light diesel railcar to evaluate and quantify the vehicle's principal characteristics under track conditions in Canada. Performed during a four-week period in 1986, the tests measured such vehicle parameters as acceleration, braking, curving, tracking stability and wheel lift. Passenger comfort criteria like ride quality, lighting, temperature and noise were also evaluated. Test procedures and instrumentation are described in the report, and the results analyzed and documented. The testing organization concluded that the vehicle could be operated safely in the required environment.			
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17. Résumé Ce rapport rend compte de la série d'essais techniques et de marche concernant le railbus diesel BRE-Leyland, modèle 141, essais destinés à évaluer et à caractériser ce dernier dans le contexte ferroviaire canadien. Répartis sur quatre semaines en 1986, ces essais ont mesuré les principaux paramètres de fonctionnement: accélération, freinage, inscription en courbe, stabilité du bogie et délestage des essieux. Du point de vue du confort des passagers, les paramètres mesurés ont été la douceur de roulement, l'éclairage, la climatisation et l'insonorisation. Les modes opératoires et les instruments mis en oeuvre sont décrits dans ce rapport, et les résultats y sont présentés et commentés. Les essais ont autorisé le contractant à déclarer le railbus comme étant de fonctionnement sûr dans le contexte considéré.			
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TP 7914E: ENGINEERING TESTS ON BRE-LEYLAND RAILBUS

SUMMARY

An engineering test program was designed to evaluate the performance of the BRE-Leyland 141 light diesel railbus under Canadian winter conditions.

The tests measured engineering performance parameters such as wheel lift, vibration, curving performance, tracking stability, acceleration, braking, as well as passenger comfort criteria such as ride quality, lighting, temperature and noise. The vibration data permits ride quality and tangent track stability analysis.

The static wheel lift tests were carried out in VIA Rail's Porte Sept shop in Ville St-Pierre, Quebec, while the road tests were conducted on CN Rail track in the Lac St-Jean region. Fully loaded tests were accomplished by placing concrete blocks weighing a total of nearly 4,000 lb (1,800 kg) on-board.

Acceleration and braking times were inferred from time history recordings of wheel revolutions. Braking distances were physically measured on the ground. Noise, tracking stability, and ride quality were measured simultaneously up to the maximum speed attainable with the vehicle (60-62 mph, 96-100 km/h). Lateral and vertical rail force measurements were taken from strain gauges that had been applied to the rails at a 4° curve, and while the railbus passed through in its loaded condition. The instrumentation for vibration measurements consisted of a lateral accelerometer on each axle, a vertical accelerometer on each end of one axle, and a tri-axial accelerometer package over one axle on the car floor. Judiciously placed thermocouples surveyed the interior vehicle temperature during the course of the tests.

The standard criterion for static wheel lift tests is that, for one-inch wheel lift, the change in wheel load for any other single wheel shall not exceed 10%. The wheel lift tests showed that the vehicle is torsionally very soft. The greatest wheel unloading was 1310 lb (595 kg) or about 9% of the static load at 3-inch wheel lift. On the basis of these results, the vehicle should have no problem with undue loss of vertical wheel load while negotiating twisted track.

Ride quality is presented in the format of the ISO Standard for reduced comfort boundaries. This standard compares the vibration spectra sensed by triaxial accelerometers (as resolved into one third octave band frequency ranges) with time endurance limits for reduced comfort as prepared by physiologists. From the ISO reduced comfort boundary diagrams, the ISO values measured for the railbus vehicle are:

ISO (hrs)	SPEED (mph, km/h)	LOCATION (A/B/centre)	LOAD CONDITION (loaded/empty)	TERRAIN/ TRACK COND.
4	46 (74)	B	loaded	hilly/jointed
1	46 (74)	A	loaded	hilly/jointed
8	46 (74)	centre	loaded	hilly/jointed
4	50 (80)	B	empty	hilly/jointed
2.5	50 (80)	A	empty	hilly/jointed
8	50 (80)	centre	empty	hilly/jointed
4	60 (96)	A	empty	flat/CWR

The times to reduced comfort in the left hand column are considered satisfactory for typical railbus trip durations.

The B-end axle is driven, while the A-end is undriven.

Hunting is defined as a limit cycle oscillation resulting from the wheel/rail interaction which causes the flange way clearance to be exhausted in a steady, repeated fashion. When the limit cycle oscillation persists for five or more cycles at an acceleration level corresponding to a wheelset lateral amplitude of 0.4 inches (1.0 cm) or more, the vehicle is considered to be hunting. From a time history of accelerometers recorded during a run at 62 mph (100 km/h), the following observations were made:

1. frequencies above 2 Hz were quickly damped;
2. a vertical resonance at about 1.2 Hz was damped in 3.5 cycles after the disturbance; and
3. a lateral resonance at about 1 Hz was damped in two cycles after the disturbance.

The behaviour of the car from the data analyzed is satisfactory. A spectrum analysis also shows minor peaks at 10.7 Hz and 12.4 Hz. The vehicle exhibited stable ride characteristics up to the maximum speed tested of 62 mph (100 km/h). No unstable modes of motion were detected during these tests. This conclusion is based on the vehicle as tested, with new wheels. Any full evaluation of stability would have to include the effects of wheel wear and extended test running at speeds above 50 mph (80 km/h). Normal practice for full qualification is an extended test at the fully worn wheel condition at the design speed (usually 15 mph, 24 km/h, in excess of maximum operating speed).

A wheel lateral-to-vertical force ratio (L/V ratio) of 0.8 is often quoted in analyses and test reports as a conservative criterion to evaluate the potential for flange climbing. The railbus tests were carried out on a 4° curve, using a balance speed of 30 mph (48 km/h). Results for the 18-40 mph (29-64 km/h) speed range tested show a single maximum L/V ratio of 0.44, with all others below 0.29. This is well within the acceptability range. No erratic behaviour was noted during the curving tests.

The vehicle took 98.2 s to reach 45 mph (72 km/h) in a distance of 4286 ft. (1306 m) in the unloaded condition. Loaded, it took 128.6 s to reach this speed in a distance of 5594 ft. (1705 m). These figures reflect the low vehicle power-to-weight ratio.

In full service braking, the vehicle took 21.5 s and 368 ft. (112 m) to brake from 48.3 mph (77 km/h) for an average of 0.62 m/s². From 64.4 mph (103 km/h) the figures were 25.5 s and 650 ft. (198 m) or 0.68 m/s². Emergency braking was not tested.

Interior light intensities were measured between 11 and 19.1 ft. candles (118205 lx) at lap height in the passenger seating area. In the aisle, intensities were 78 ft. candles (839 lx) at eye level and 7 ft. candles (75 lx) at floor level.

The temperature distribution was surveyed on a sunny day with the exterior temperature varying from -6°C to -8°C. Temperature distribution inside the car was greatly affected by the sun. On the shady side, temperatures in the passenger compartments varied from 22°C to 28°C at speeds of 30 and 50 mph (40 and 80 km/h). On the sunny side, in direct sunlight, temperatures varied from 29°C to 37°C at 30 mph (48 km/h) and 26°C to 36°C at 50 mph (80 km/h). On the same sunny side, lower down in shaded areas, temperatures were about 24°C.

Sound intensities were measured at eight selected positions in the car at speeds of between 37 and 47 mph (59-75 km/h). Noise levels were in the range of 64 to 66 dBA with an increase of about 5 dBA near the side doors and a large increase of about 10 dBA in the passenger area when the auxiliary heater fans were on.

TP 7914E : EVALUATION TECHNIQUE DU RAILBUS BRE-LEYLAND

SOMMAIRE

Un programme d'essais a été élaboré en vue d'évaluer le comportement du railbus diesel BRE-Leyland, modèle 141, dans le contexte hivernal du Canada.

Les principaux paramètres mesurés ont été le délestage des essieux et la stabilité des bogies, les niveaux vibratoires, l'inscription en courbe, les temps d'accélération et de freinage et, du point de vue confort des passagers, la douceur de roulement, l'éclairage, la climatisation et l'insonorisation. Les tests vibratoires ont débouché sur une analyse chiffrée de la douceur de roulement et de la stabilité dans les alignements.

Les essais statiques de délestage ont eu lieu dans l'atelier Porte Sept de VIA Rail, à Ville St-Pierre (Québec), tandis que les essais dynamiques se sont déroulés dans la région du lac St-Jean, sur une ligne appartenant au CN. Pour les essais en charge, des blocs de béton d'un poids total de quelque 4,000 lb (1 800 kg) ont été utilisés.

Les temps d'accélération et de freinage ont été extraits des enregistrements faits sur les vitesses de rotation des roues, tandis que les distances de freinage ont été mesurées par chaînage au sol. Le bruit, la stabilité de marche et la douceur de roulement ont été mesurés simultanément, à des vitesses croissant jusqu'à un maximum de 60-62 mi/h (96-100 km/h). Les forces transversales et verticales ont été mesurées à l'aide d'extensomètres fixés aux rails, dans une courbe de 4° sur laquelle le railbus a circulé à pleine charge. Pour les essais vibratoires, des capteurs d'accélération ont été utilisés: un pour les accélérations transversales sur chaque essieu, un pour les accélérations verticales à chaque extrémité des essieux et un groupe accélérométrique triaxial sur le plancher du véhicule, au-dessus d'un des essieux. Enfin, des thermocouples judicieusement placés ont permis de mesurer la température à l'intérieur du véhicule, tout au long des essais.

La norme applicable aux essais statiques de délestage est la suivante: un délestage de 1 pouce d'une roue ne doit pas entraîner, sur toute autre roue, une variation supérieure à 10 p. 100. Ces essais ont montré que la suspension du véhicule est très élastique en torsion, le délestage maximum observé ayant été de 1310 lb (595 kg), soit quelque 9 p. 100 de la charge statique à 3 pouces de délestage. Ces résultats autorisent à dire que le véhicule ne risque pas de connaître des variations indues dans les forces verticales en circulant sur un terrain vallonné.

Quant aux essais de douceur de roulement, ils se sont inspirés de la norme ISO concernant la limite au confort réduit. Pour cela, les spectres vibratoires transmis par les accéléromètres triaxiaux (délimités en gammes de fréquences n'excédant pas un tiers d'octave) ont été comparés aux limites à la capacité réduite par fatigue proposées par les experts en physiologie. A partir des diagrammes sur la limite au confort réduit, les valeurs normalisées ISO observées à l'égard du railbus ont été les suivantes:

ISO (h)	VITESSE (mi/h, km/h)	EMPLACEMENT A/B/centre	ESSIEU (en charge/libre)	ETAT DU TERRAIN/ VOIE
4	46 (74)	B	en charge	vallonné/à joints
1	46 (74)	A	en charge	vallonné/à joints
8	46 (74)	centre	en charge	vallonné/à joints
4	50 (80)	B	libre	vallonné/à joints
2.5	50 (80)	A	libre	vallonné/à joints
8	50 (80)	centre	libre	vallonné/à joints
4	60 (96)	A	libre	plat/LRS

Les délais d'apparition de confort réduit indiqués dans la colonne de gauche sont considérés comme acceptables, eu égard aux temps globaux de parcours dans le cas d'un railbus.

L'essieu à l'extrémité B est entraîné, alors que celui à l'extrémité A ne l'est pas.

Le lacet est un phénomène défini comme étant des oscillations périodiques limites provoquées par les forces de rappel et qui font que le jeu entre le boudin et le flanc de rail varie continuellement et cycliquement. Il y a lacet lorsque les oscillations périodiques limites persistent durant cinq périodes, ou plus, à un niveau d'accélération correspondant à un déplacement transversal de l'essieu monté de 0,4 pouces (1 cm) ou plus. A partir des diagrammes d'accélération enregistrés à la vitesse de 62 mi/h (100 km/h), les observations suivantes ont été faites:

1. les oscillations supérieures à 2 Hz ont été rapidement amorties,
2. une oscillation verticale à la fréquence de résonance d'environ 1,2 Hz a été amortie au bout de 3,5 périodes, et
3. une oscillation transversale à la fréquence de résonance d'environ 1 Hz a été amortie au bout de deux périodes.

Partant de l'analyse des données, il est permis de considérer la tenue de route de la voiture comme étant satisfaisante. Des faibles crêtes ont été observées à 10,7 et 12,4 Hz sur le spectre tracé. Le véhicule s'est révélé stable jusqu'à sa vitesse maximale de 62 mi/h (100 km/h). Aucune instabilité de marche n'a été notée. Ces observations concernent le véhicule essayé, équipé de roues neuves. Pour être complète, l'évaluation de la stabilité doit tenir compte de l'effet de l'usure des roues et comporter des essais prolongés à des vitesses supérieures à 50 mi/h (80 km/h). Les essais de qualification prévoient en outre un essai de marche prolongé avec des roues à profil d'usure extrême et à la vitesse nominale qui est généralement de 15 mi/h (24 km/h) supérieure à la vitesse maximale de service.

Les rapports et les analyses de recherche donnent couramment 0,8 comme la valeur critique du rapport des forces transversales aux forces verticales (rapport t/v), pour ce qui concerne la tendance au passage du boudin sur le rail. Les essais d'inscription ont eu lieu dans une courbe à 4°, à la vitesse d'équilibre de 30 mi/h (48 km/h). Les résultats des essais faits dans la fourchette 18-40 mi/h (29 à 64 km/h) montrent une valeur maximum de 0,44, atteinte une seule fois, les autres restant inférieures à 0,29. Cette valeur se situe donc à l'intérieur des limites sûres. Aucun comportement erratique n'a été observé durant ces essais.

Sans charge, le véhicule a mis 98,2 secondes pour atteindre 45 mi/h (72 km/h), sur une distance de 4286 pieds (1 306 m). En charge, il lui a fallu 128,6 secondes pour atteindre cette vitesse et 5594 pieds (1 705 m). Ces chiffres reflètent un rapport puissance/poids plutôt bas.

En freinage normal, il lui a fallu 21,5 secondes et 368 pieds (112 m) pour s'arrêter, à partir de 48,3 mi/h (77 km/h), pour une moyenne de 0,62 m/s². A partir de 64,4 mi/h (103 km/h), les chiffres sont de 25,5 secondes et 650 pieds (198 m), soit 0,68 m/s². Il n'y a pas eu d'essai de freinage d'urgence.

L'éclairage intérieur mesuré a été de 11 à 19,1 pieds bougies (118-205 lx) au niveau du giron d'une personne assise. Dans le couloir, il a été de 78 pieds bougies (839 lx) et de 7 pieds bougies (75 lx), au niveau de l'oeil et du plancher, respectivement.

La distribution de la température intérieure a été mesurée par jour ensoleillé, alors qu'à l'extérieur, il faisait de -6 à -8°C. Cette distribution s'est révélée fortement influencée par l'effet calorique du soleil. Côté ombre, dans le compartiment voyageurs, la température a varié entre 22 et 28°C à 30 et 50 mi/h (40 et 80 km/h). Côté soleil, elle a varié, dans les zones directement éclairées, de 29 à 37° à 30 mi/h (48 km/h) et de 26 à 36° à 50 mi/h (80 km/h). De ce même côté, mais à l'ombre, la température a avoisiné 24°C.

Les niveaux de pression acoustique ont été mesurés en 8 endroits sélectionnés dans la voiture, aux vitesses comprises entre 37 et 47 mi/h (59 à 75 km/h). Ils ont été de 64 à 66 dBA, augmentant de quelque 5 dBA près des portes et de quelque 10 dBA à l'intérieur du compartiment voyageurs, lorsque les aérothermes de chauffage d'appoint fonctionnaient.

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1.0 INTRODUCTION

In February 1986 the Railway Laboratory of the National Research Council at the request of the Transportation Development Centre agreed to carry out a series of vehicle engineering tests to evaluate the performance of the BRE-Leyland 141 Light Diesel Railcar.

These tests were completed between February 13th and March 14th, 1986.

This report describes the procedures employed and presents the results obtained.

2.0 TEST DESCRIPTION

2.1 Work Statement

The work carried out by the NRC was confined to the following areas - wheel lift, vibration, curving performance, acceleration, braking, lighting, temperature and noise.

2.2 Test Sites

The initial tests, static wheel lift, were carried out by the National Research Council while the vehicle was in VIA Rail's Porte Sept shop.

The Lac St-Jean Region of Canadian National Railways was designated for the road tests. This region is predominantly curved, in fact there are almost 600 curves in 200 miles of track. The only length of tangent track found without road crossings, just west of Hébertville Station, was of indifferent quality, and barely 4 miles (6.4 km) in length, not long enough for the relatively low powered railbus to attain its maximum speed, but sufficient for testing at up to 50 mph (80 km/h). Another length of track, this one 9 miles (14.5 km), between St. Lambert and St. Bruno in the St. Hyacinthe region was made available later, to enable speeds up to 60 mph (96.5 km/h) to be reached.

The curving site, chosen primarily for its accessibility by road, was exactly 4° and had a balance speed of 30 mph (48 km/h).

This was located a further 20 miles (32 km) west of Hébertville Station, near Chambord.

2.3 Test Procedures

2.3.1 Wheel lift

The vehicle shock absorbers were removed, and specially designed brackets which allowed the bus to be lifted from under the axles were installed. The railbus was then lifted clear of the tracks with hydraulic jacks on calibrated load cells. When the load on all axle ends had been noted, one wheel was then raised in one quarter inch (64 mm) increments until it was $3\frac{1}{2}$ inches (889 mm) clear of the track, at which time the spring deflections were measured. The wheel was then incrementally lowered.

2.3.2 Vibration measurement during steady speed runs

Sufficient instrumentation was employed to measure noise, ride quality and tracking stability simultaneously. Results of the noise survey are presented in Appendix 1.

Ride quality was measured in both the "loaded" and "unloaded" conditions to the ISO format using one triaxial accelerometer package in the centre of the car floor, and another over one axle. A single, lateral, accelerometer was placed over the other axle.

Tracking stability was measured through a lateral accelerometer at one end of each axle and a vertical accelerometer on each end of one axle. Tests were carried out at 20, 30, 40 and 50 mph (32, 48, 64 and 80 km/h) and in each direction in the Lac St-Jean Region and up to 60 mph (96.5 km/h) in the St-Hyacinthe region.

2.3.3 Curving performance

Lateral and vertical rail force measurements were taken from strain gauges applied to the track [Fig. 1] and physically calibrated at mile 156, Lac St-Jean. The railbus, in its "loaded" condition, was intended to round the curve at 20, 30 and 40 mph (32, 48, and 64 km/h) in each direction; however, the southbound approach was up a slight incline and the maximum speed attained in that direction was only 32 mph (51 km/h).

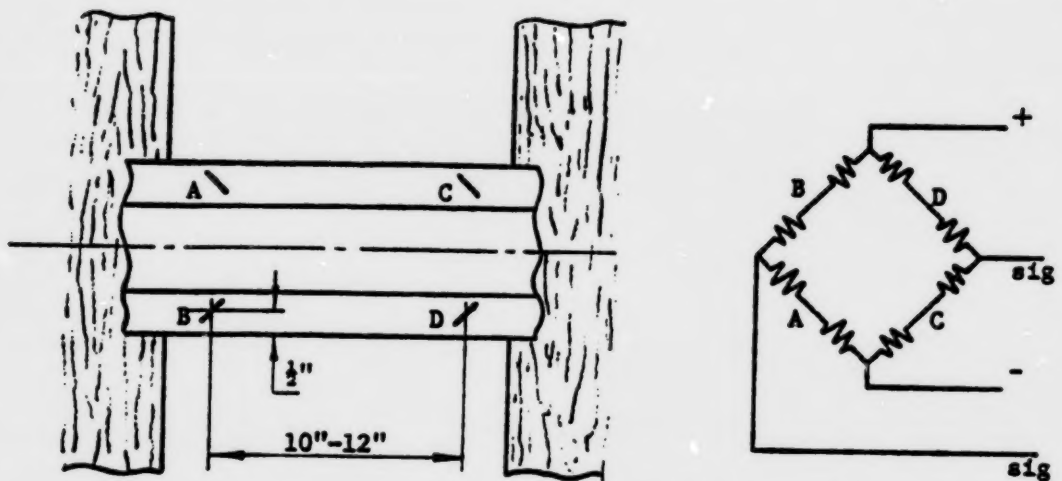


FIGURE 1 (a). LATERAL FORCE MEASUREMENT

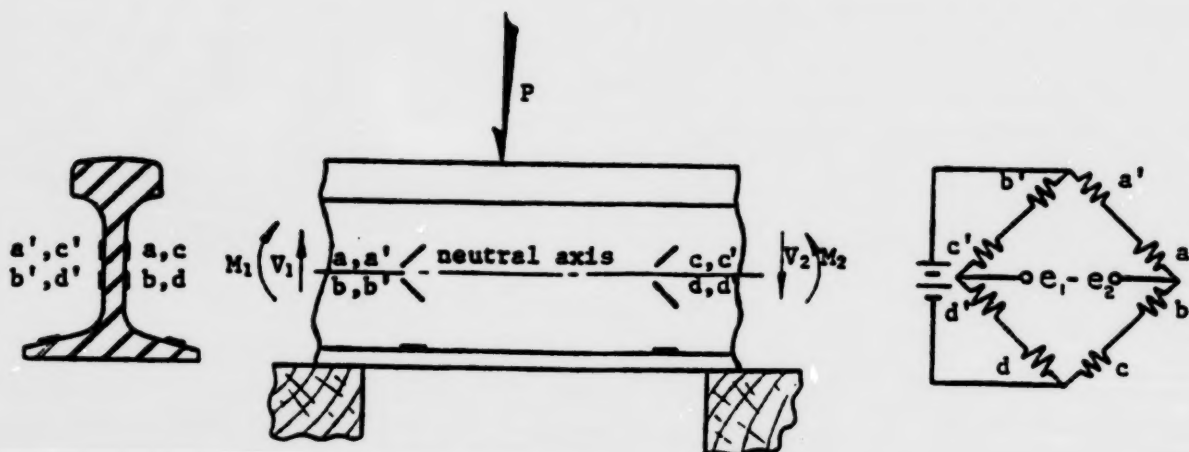


FIGURE 1 (b). VERTICAL FORCE MEASUREMENT

2.3.4 Acceleration

A magnet was attached to one axle and a pick up coil attached to the underside of the car floor, and each revolution of the wheel was recorded on FM tape. Stop watch readings were also taken. Results are presented on a graph [Fig. 1(c)].

2.3.5 Braking Distances

Braking distances were physically measured with the railbus travelling at different speeds in each direction over a marked stretch of flat, tangent track.

2.3.6 Lighting Survey

This survey was carried out late one evening between Hébertville Station and Jonquière, a distance of about 40 miles (64 km). The instrument used was a Lite-Mate Photometer System.

2.3.7 Noise Survey

The noise level intensity was measured throughout the vehicle during the course of these test procedures by Mr. J. Hammer of the National Research Council Engine Laboratory. His report is included here as Appendix 1.

2.3.8 Temperature Survey

Thermocouples were placed at ten locations throughout the railbus. A full description of their positions, test conditions and the results are given in Appendix 2.

2.4 Vehicle Loads

The estimated loads on the vehicle during the tests are arrived at as follows.

Vehicle Loads	"Loaded" Condition		"Unloaded" Condition	
	LBS	KG	LBS	KG
Passengers	13 @170 =	2210 1005	12 x 170 =	2040 927
Cement blocks	66 x 55 =	3630 1650		
Instrumentation		350 159	350	159
Spares		400 182	400	182
Sand bags	3 x 88 =	<u>264</u> <u>120</u>	2 x 88 =	<u>176</u> <u>80</u>
Total		6854 3116	2966	1348

TABLE 1 LOAD CALCULATIONS

This results in a difference between the two conditions of 3,888 lbs or 1,767 kg.

3.0 RESULTS

3.1 Wheel Life, Spring Deflections and Wheel Load Relations

Wheel lift, spring deflections and wheel load relations are shown in Table 2 and Table 3 respectively.

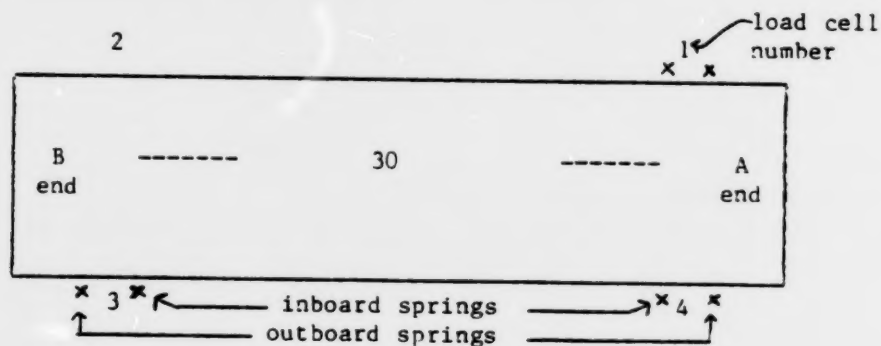


Figure 1 (c) DIAGRAM OF LOAD CELL POSITIONS AND SPRING DEFLECTION NOMENCLATURE

Jacking at wheel #4 in 1/4" increments to a total of 3-1/2"

Figure 1(c) defines the nomenclature used in these tables and Figure 1(d) is a plot of Table 3 results.

	INBOARD	OUTBOARD	AVERAGE		LOAD	
	In.	In.	In.	cm.	lbs	kg
#4	3/4	13/16	25/32	1.98	1040	473
#3	-11/16	- 3/4	- 23/32	1.82	1310	595
#2	3/4	7/8	13/16	2.06	1330	604
#1	- 5/8	- 5/8	- 5/8	1.56	1110	504

TABLE 2 SPRING DEFLECTIONS

= .734 in. deflection with 1198 lbs force = 1632 lbs/inch
 = 1.864 cm deflection with 544 kg force = 292 kg/cm

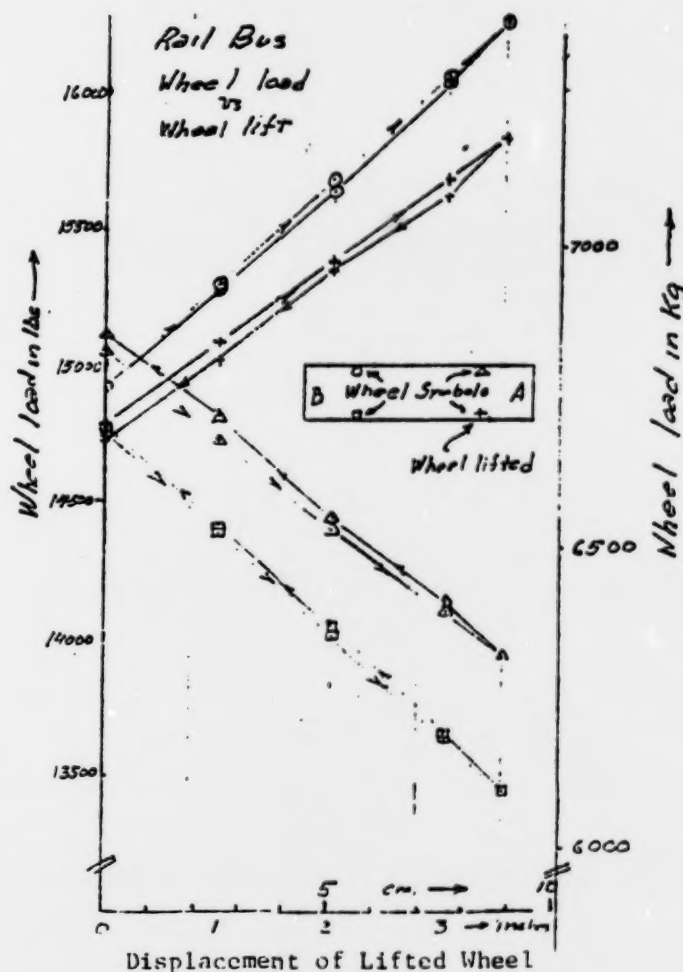


Figure 1(d) WHEEL LOAD AS A FUNCTION OF WHEEL LIFT

L O A D				DISPLMT.
Cell #2 lbs	Cell #3 lbs	Cell #1 lbs	Cell #4 lbs	at Cell #4 inches
14920	14750	15050	14780	0
15020	14660	14930	14860	1/4
15120	14560	14880	14940	1/2
15210	14470	14790	15020	3/4
15300	14380	14720	15090	1
15390	14290	14650	15160	1-1/4
15490	14190	14520	15240	1-1/2
15580	14100	14480	15310	1-3/4
15680	14010	14400	15380	2
15770	13910	14330	15460	2-1/4
15860	13820	14250	15530	2-1/2
15970	13720	14170	15610	2-3/4
16060	13630	14100	15680	3
16150	13540	14040	15750	3-1/4
16250	13440	13940	15820	3-1/2
16030	13660	14140	15620	3
15830	13850	14320	15470	2-1/2
15650	14040	14450	15320	2
15450	14230	14640	15160	1-1/2
15270	14410	14810	15010	1
15080	14600	14970	14870	1/2
14910	14780	15110	14720	0

TABLE 3 WHEEL LIFT, LOAD TABLE

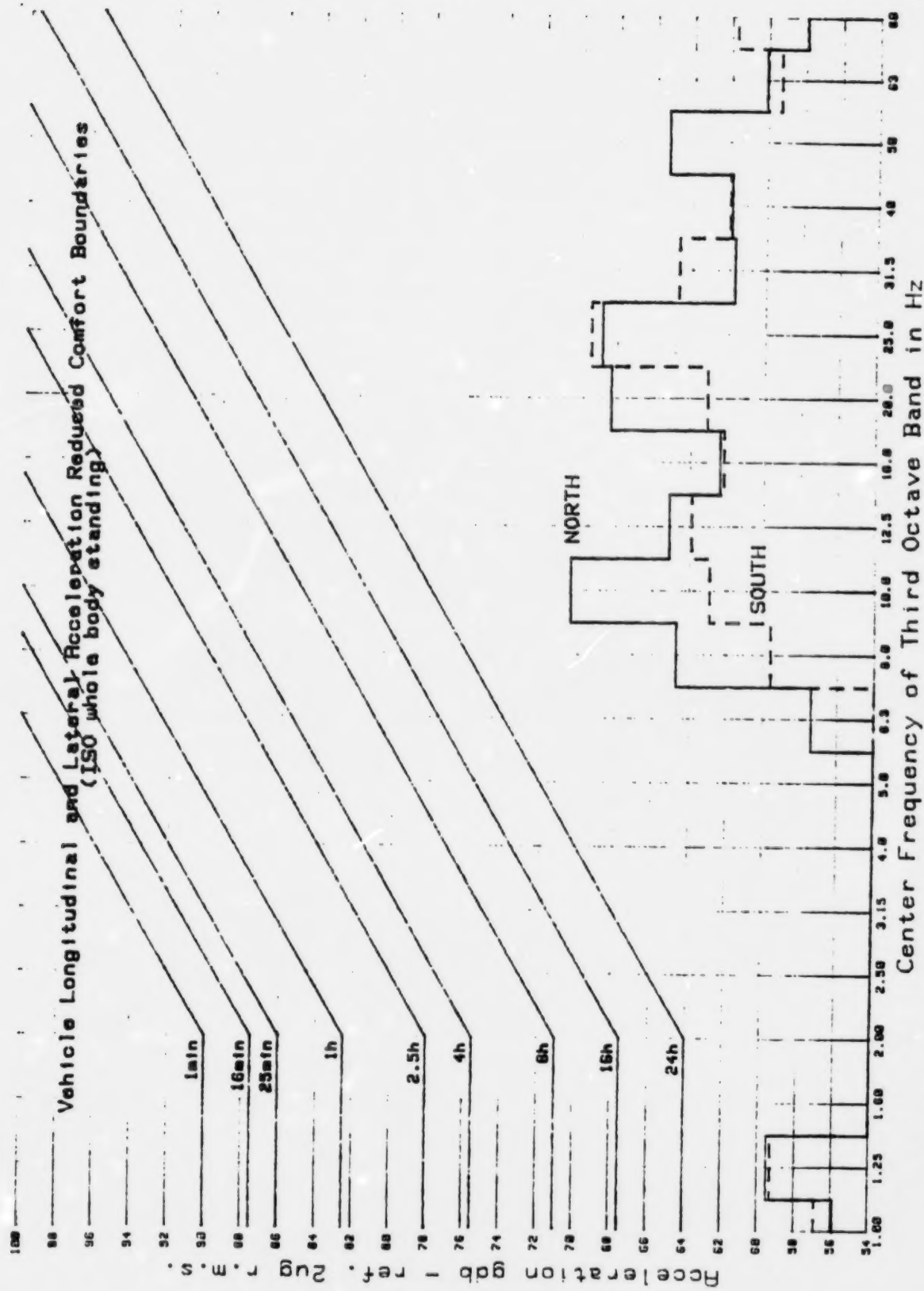
3.2 Steady Speed Runs

3.2.1 Ride quality charts

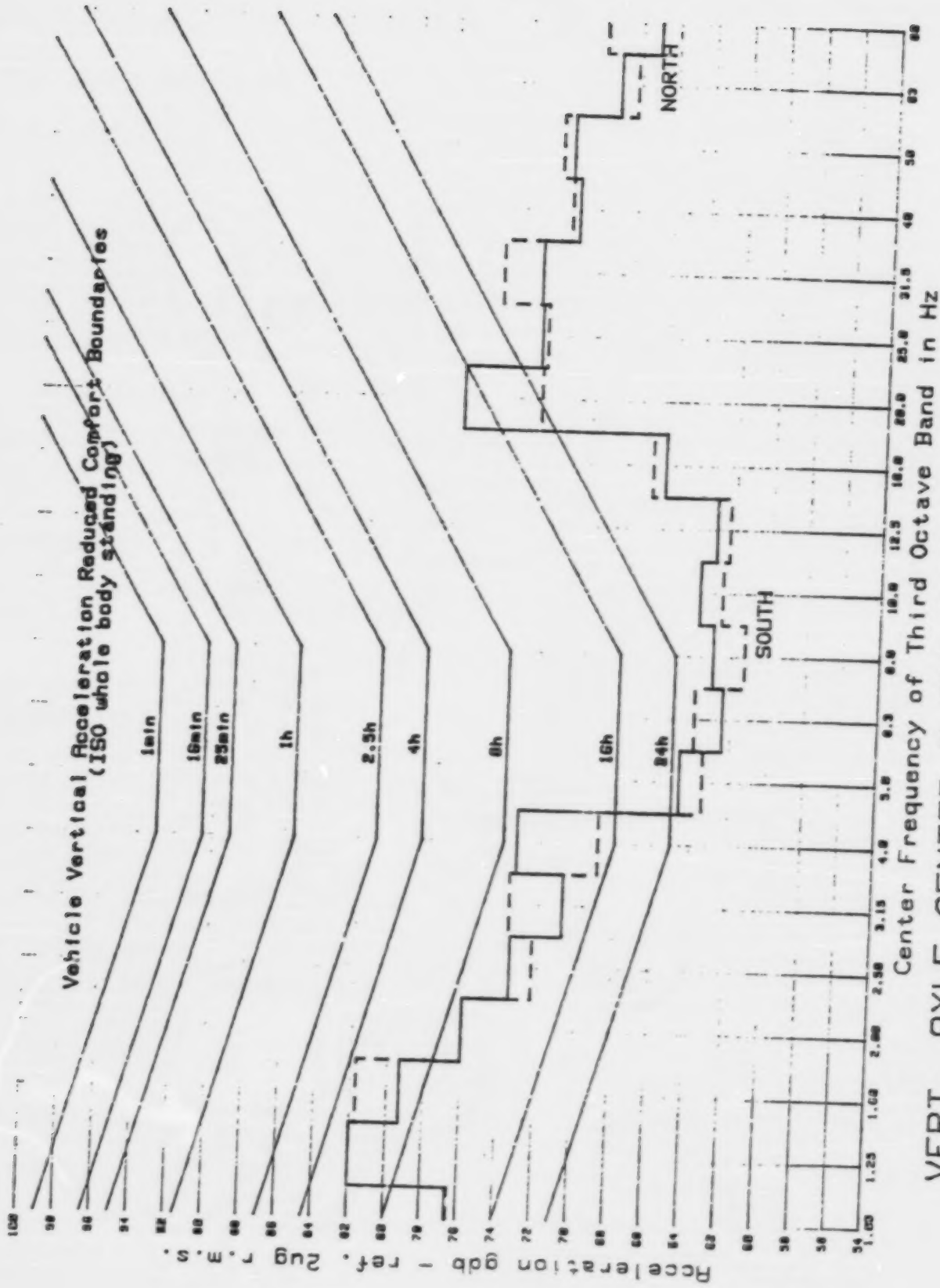
Ride quality results are presented in the format of the ISO Standard for reduced comfort boundaries. This standard compares the vibration spectra sensed by triaxial accelerometers (as resolved into one third octave band frequency ranges) with time endurance limits for reduced comfort as prepared by physiologists. The figure number for the comfort chart for the situations presented can be found from the following chart.

ACCELEROMETER POSITION	SPEED/AXIS	46 mph (Fig.)	50 mph (Fig.)	60 mph (Fig.)
triaxial accel. over "B" end axle	longitudinal	2	9	-
	vertical	3	10	-
	transverse	4	11	-
triaxial accel. at car centre	longitudinal	5	12	-
	vertical	6	13	-
	transverse	7	14	-
triaxial accel. over "A" end axle	longitudinal	-	-	16
	vertical	-	-	17
	transverse	8	15	18
CONDITION		Loaded	Empty	Empty
LOCATION		Chicoutimi	Chicoutimi	St. Hyacinthe
RAIL CONDITION		hilly jointed	hilly jointed	CWR good

TABLE 4 GUIDE TO RIDE QUALITY FIGURES

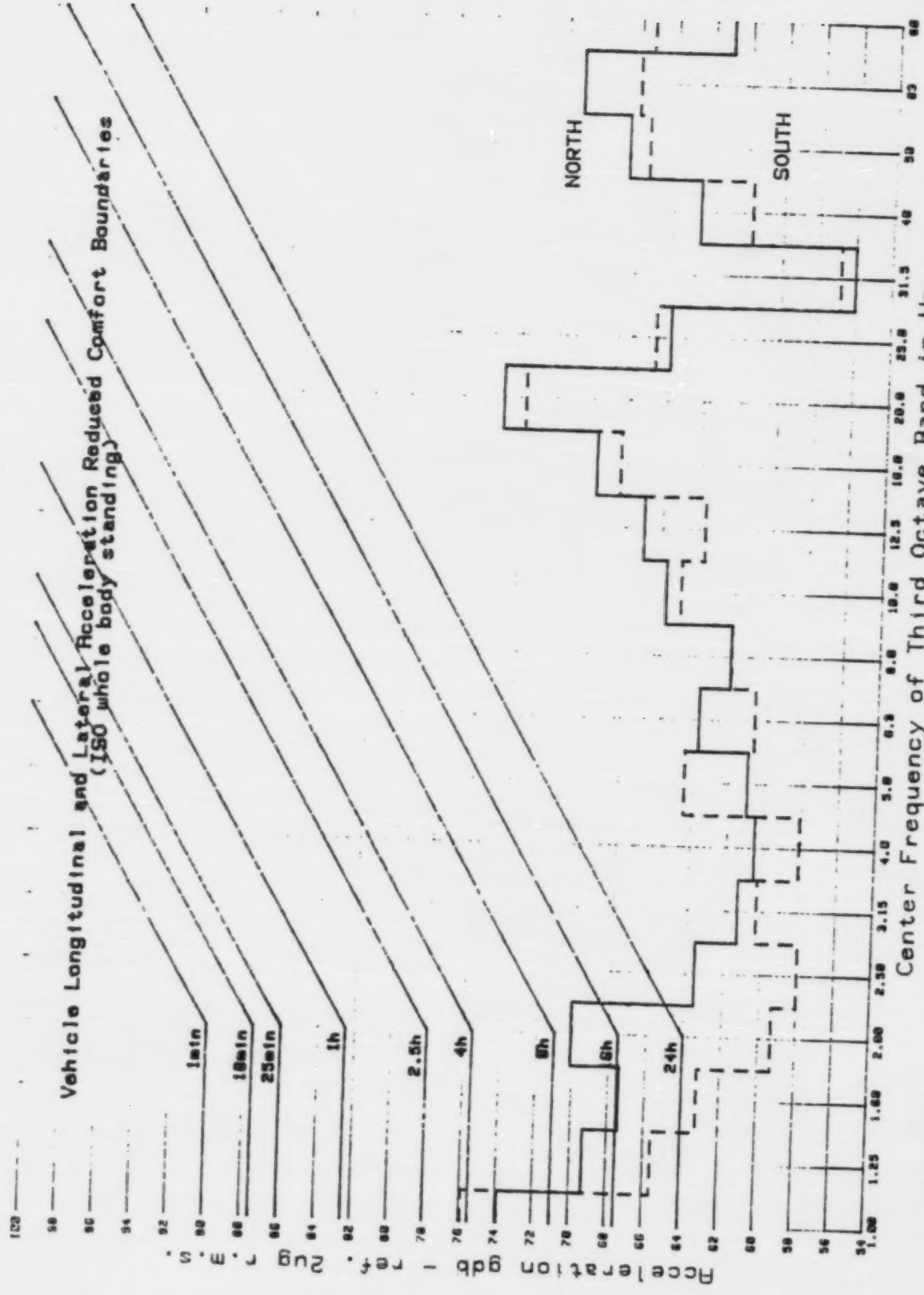


LONG. AXLE CENTER B-END-BREL75-45MPH-LOADED



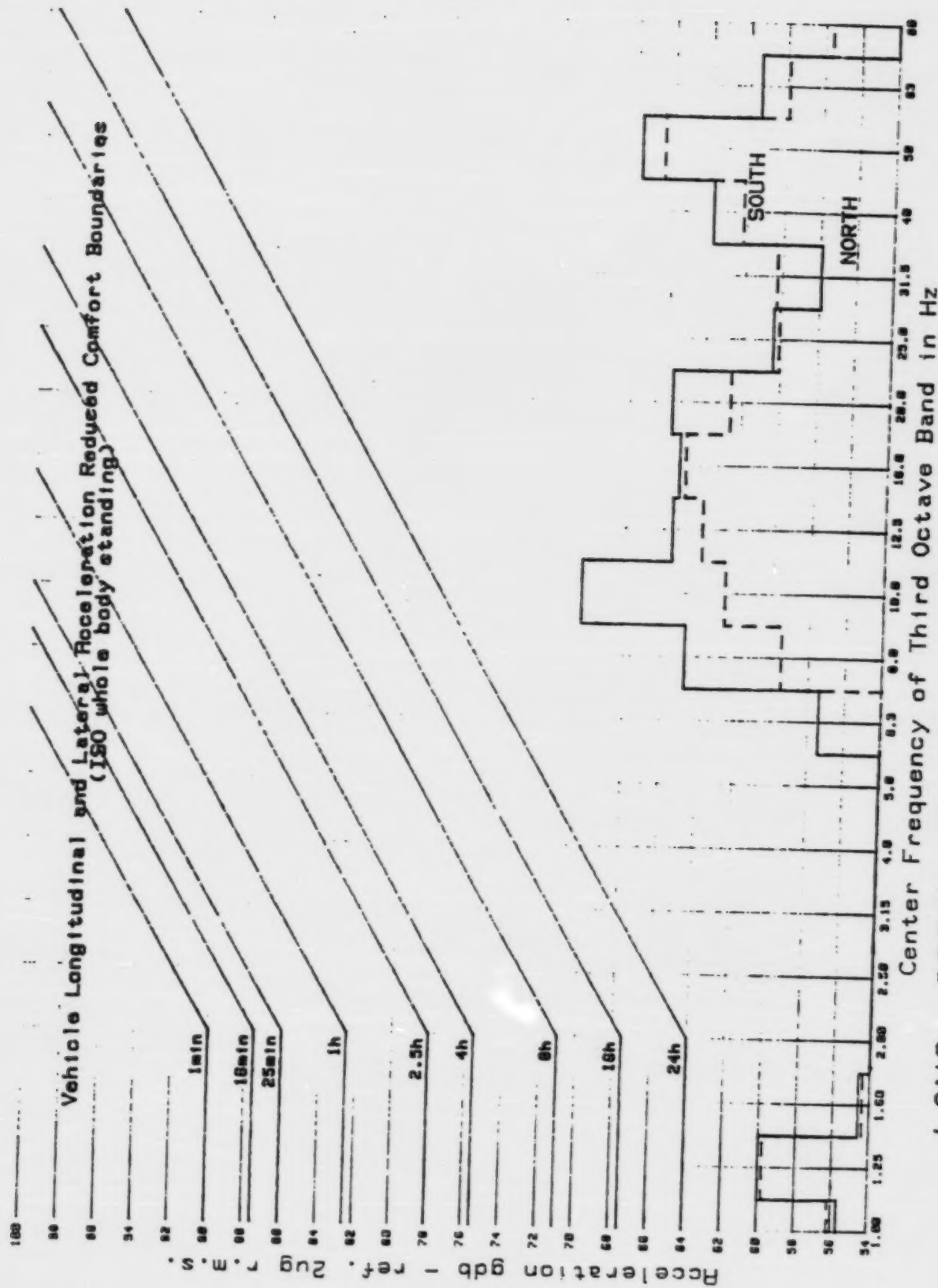
VERT. AXLE CENTER B-END-BREL75-45MPH-LOADED

Figure 3



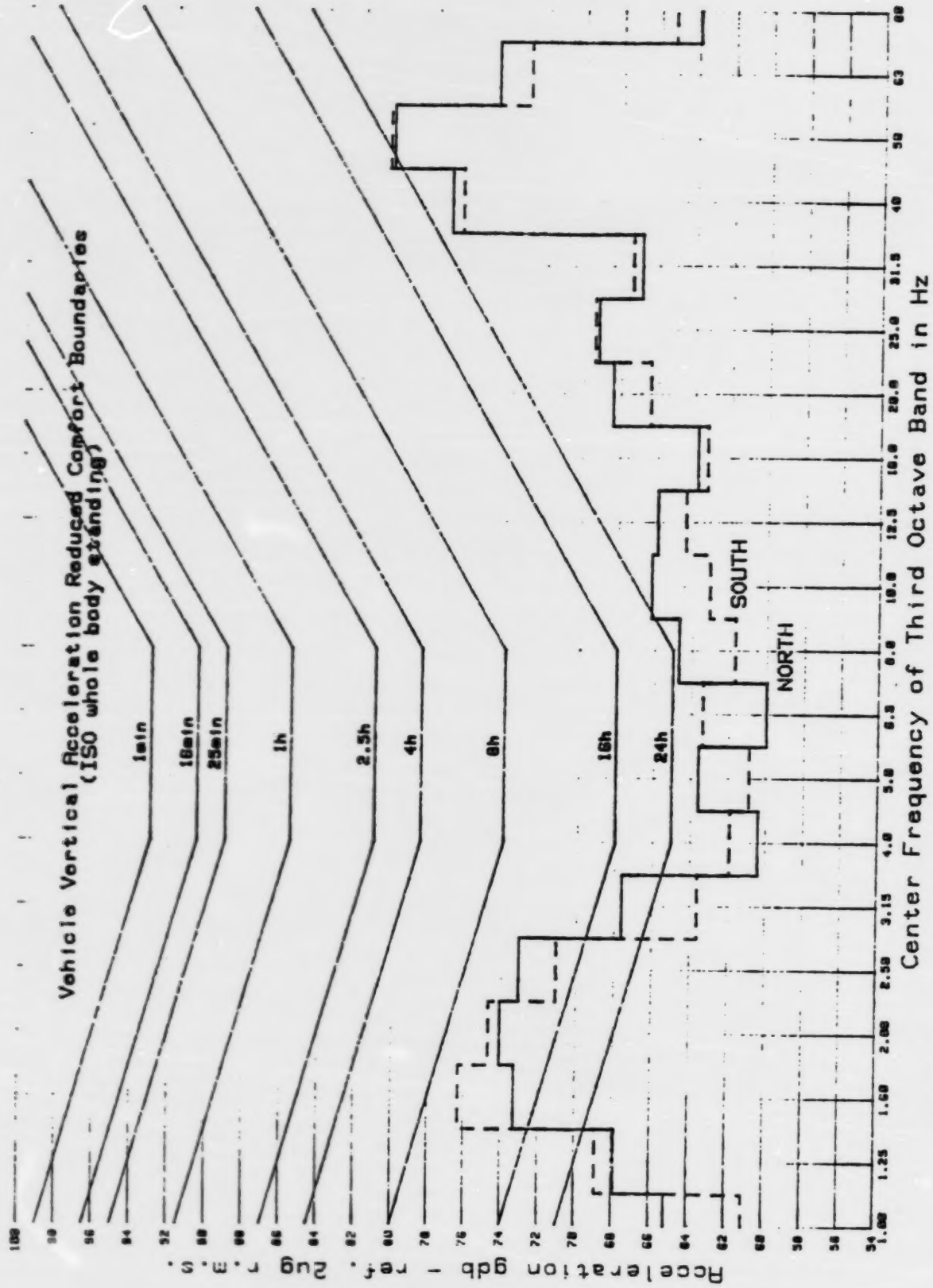
TRANS. AXLE CENTER B-END-BREL75-45MPH-LOADED

Figure 4



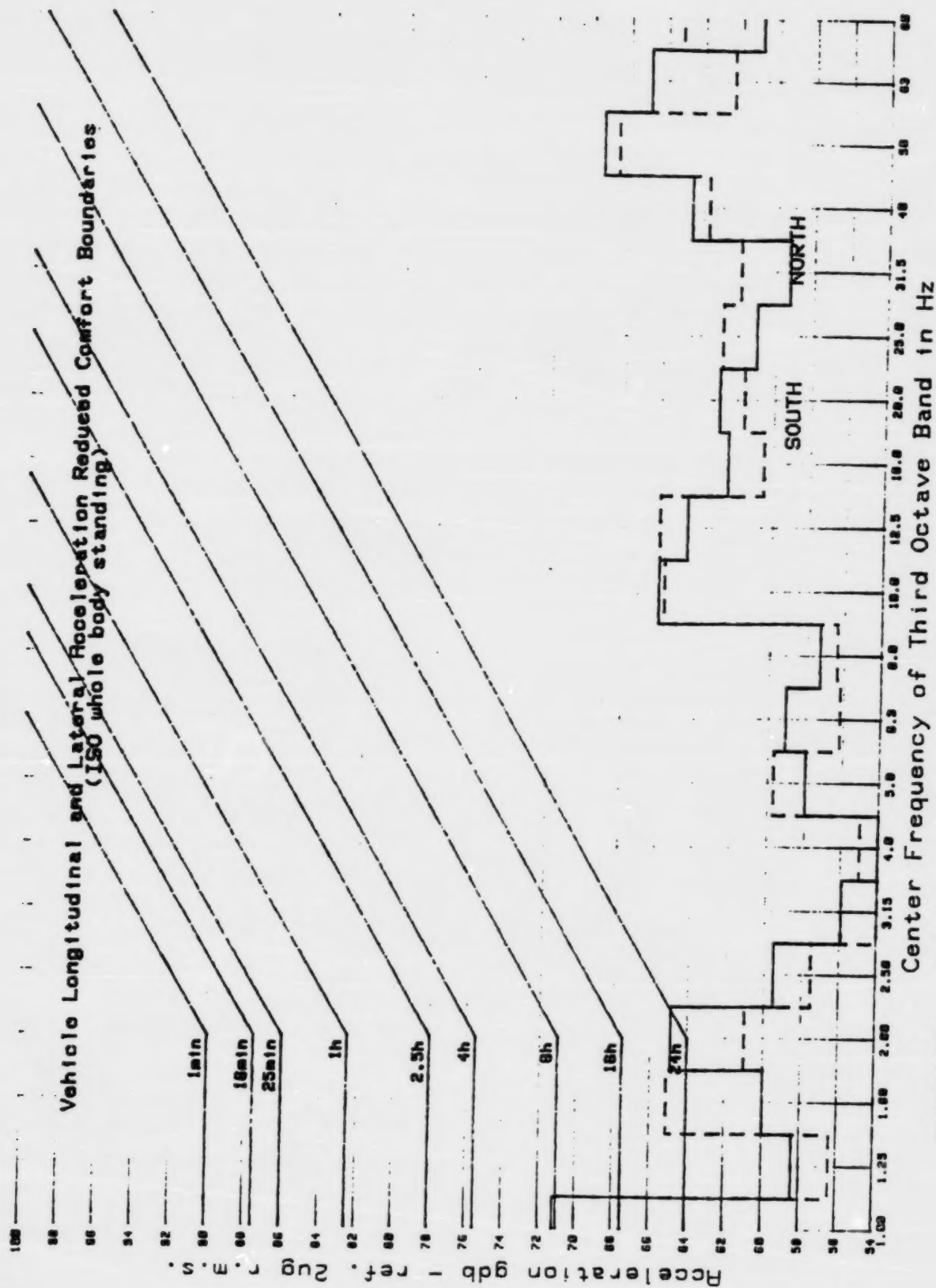
LONG. COACH CENTER -BREL75-45MPH-LOADED

Figure 5



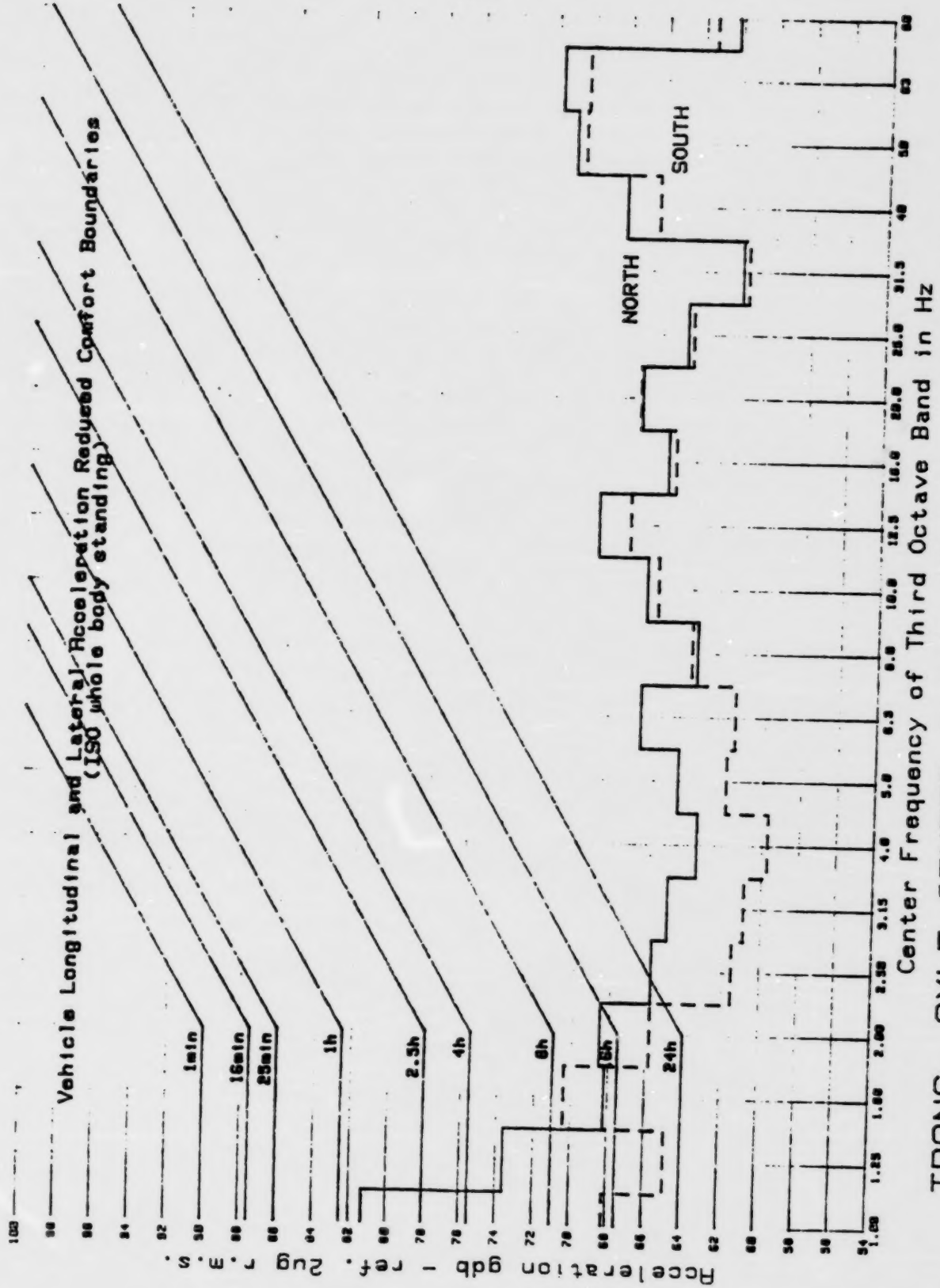
VERT. COACH CENTER -BREL75-45MPH-LOADED

Figure 6



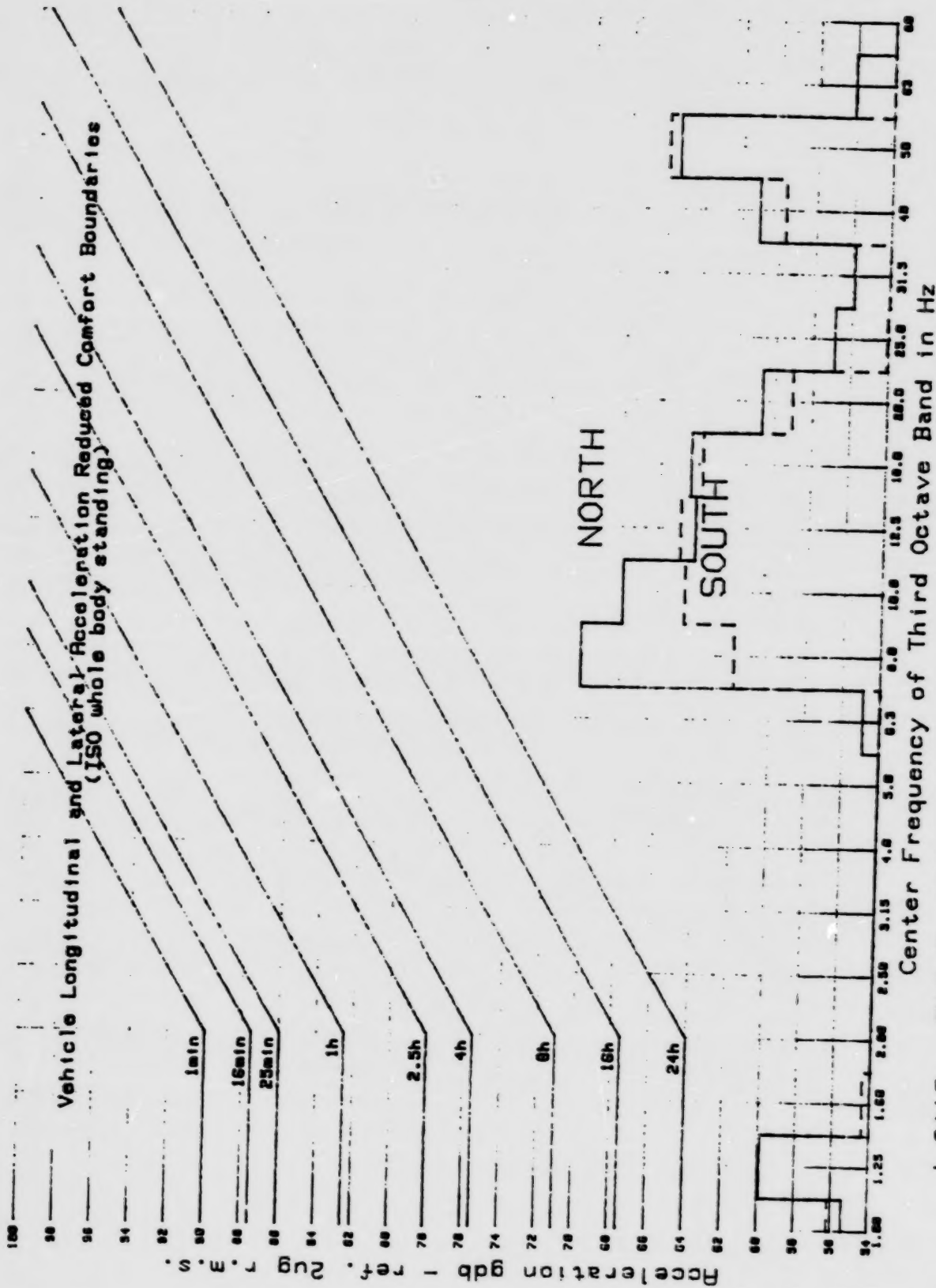
TRANS. COACH CENTER -BREL75-45MPH-LOADED

Figure 7



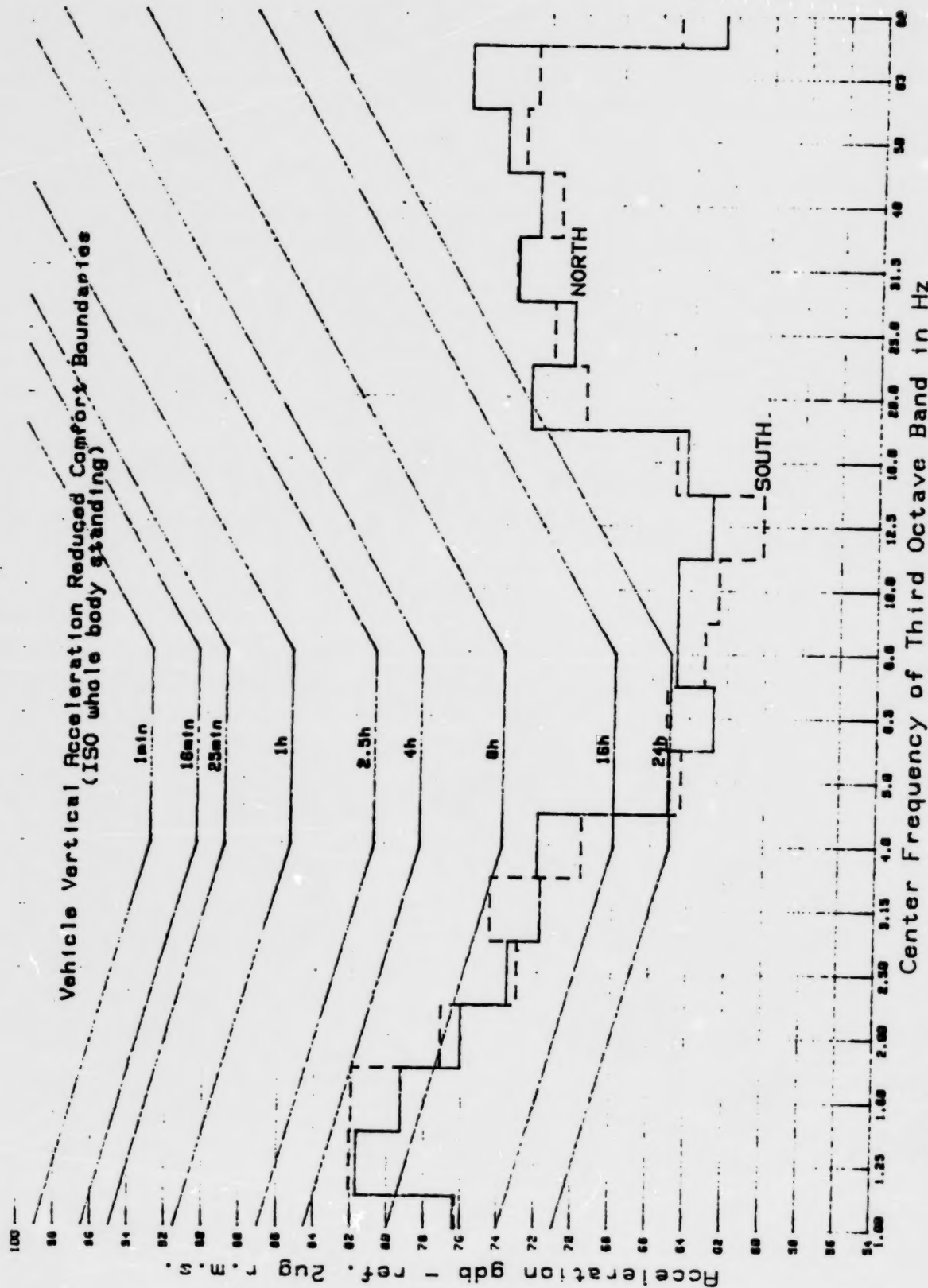
TRANS. AXLE CENTER A-END-BREL75-45MPH-LOADED

Figure 8



LONG. AXLE CENTER B-END-BREL75-50MPH-EMPTY

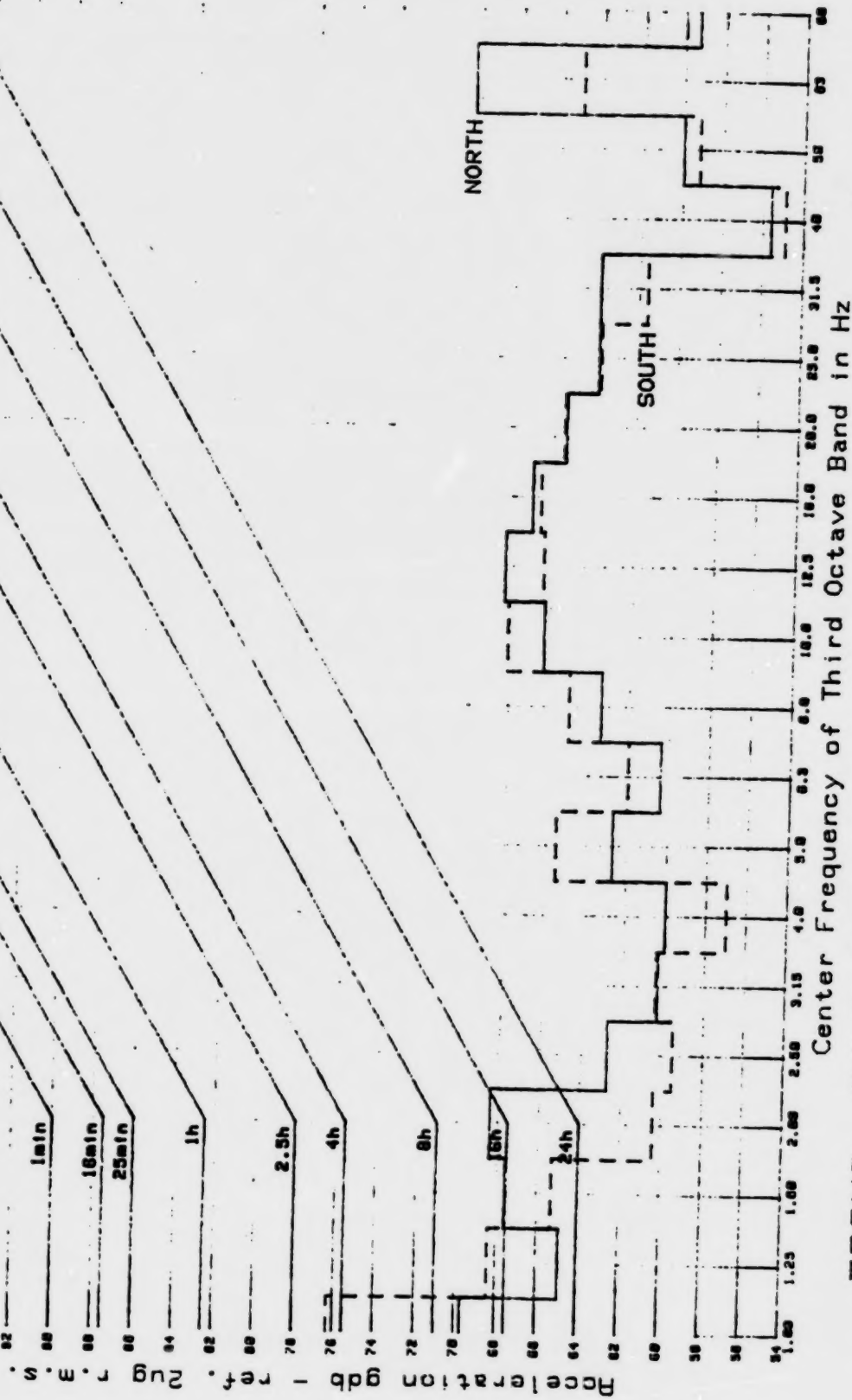
Figure 9



VERT. AXLE CENTER B-END-BREL75-50MPH-EMPTY

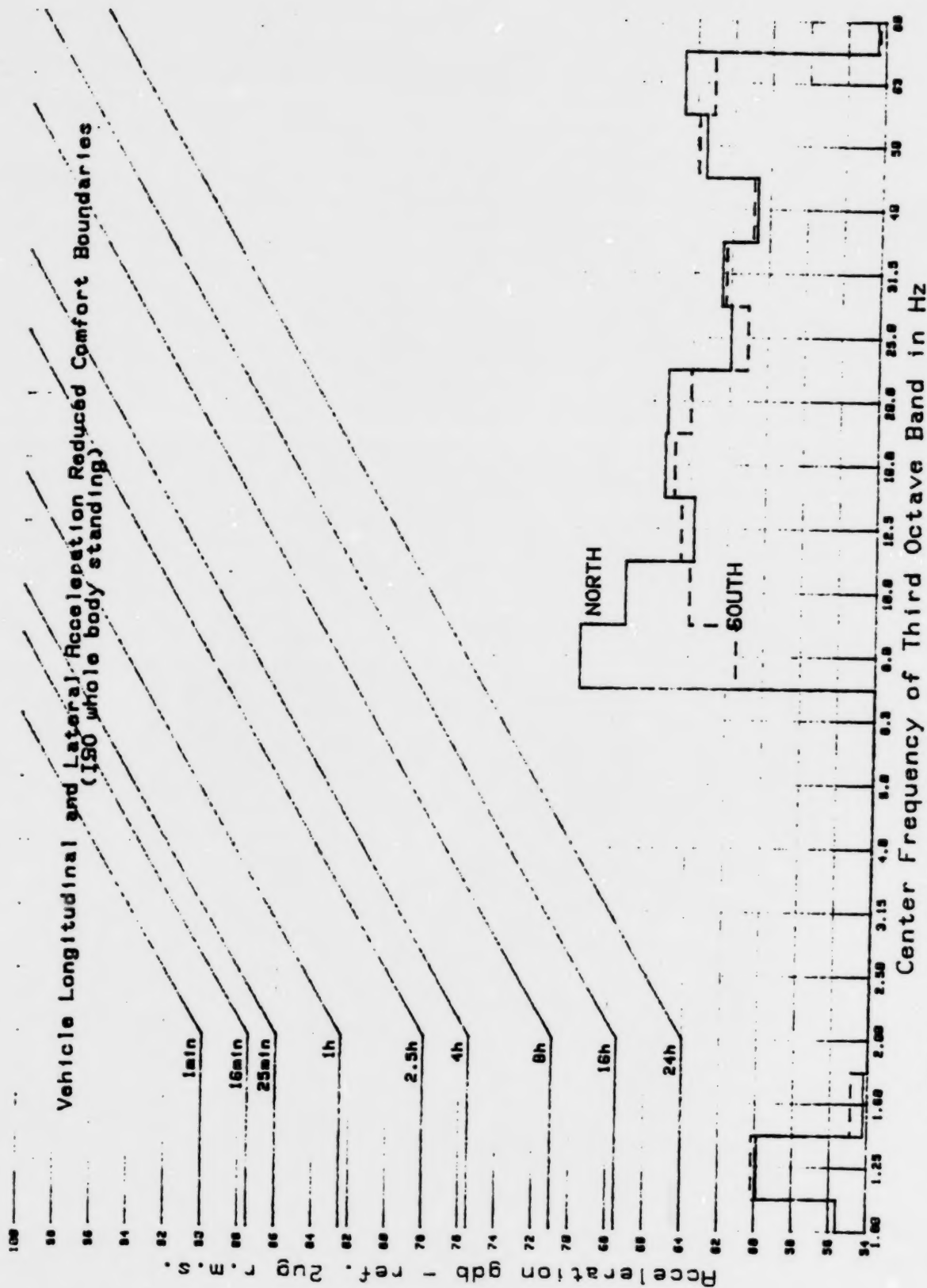
Figure 10

Vehicle Longitudinal and Lateral Acceleration Reduced Comfort Boundaries
(ISO whole body standing)



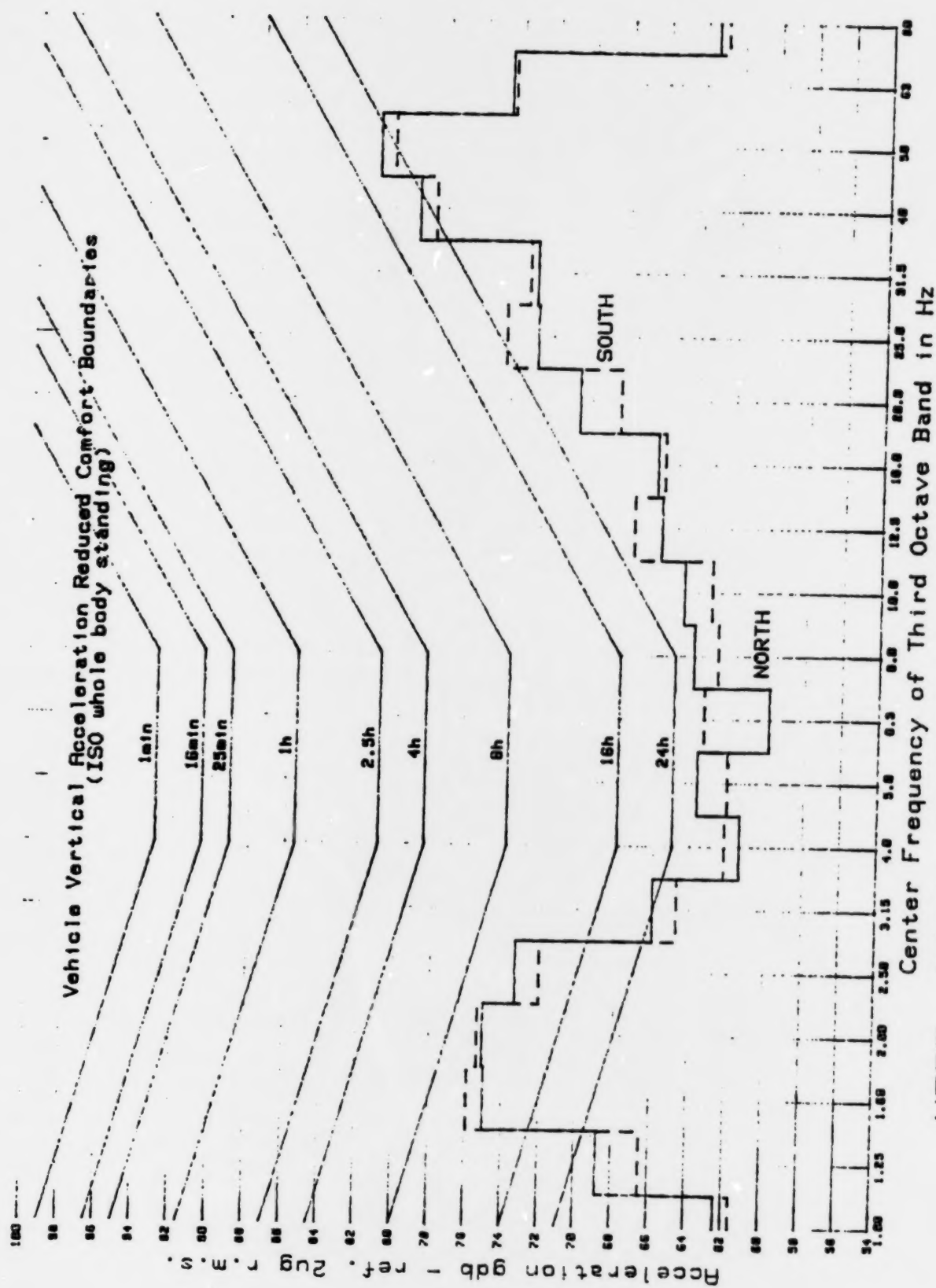
TRANS. AXLE CENTER B-END-BREL75-50MPH-EMPTY

Figure 11



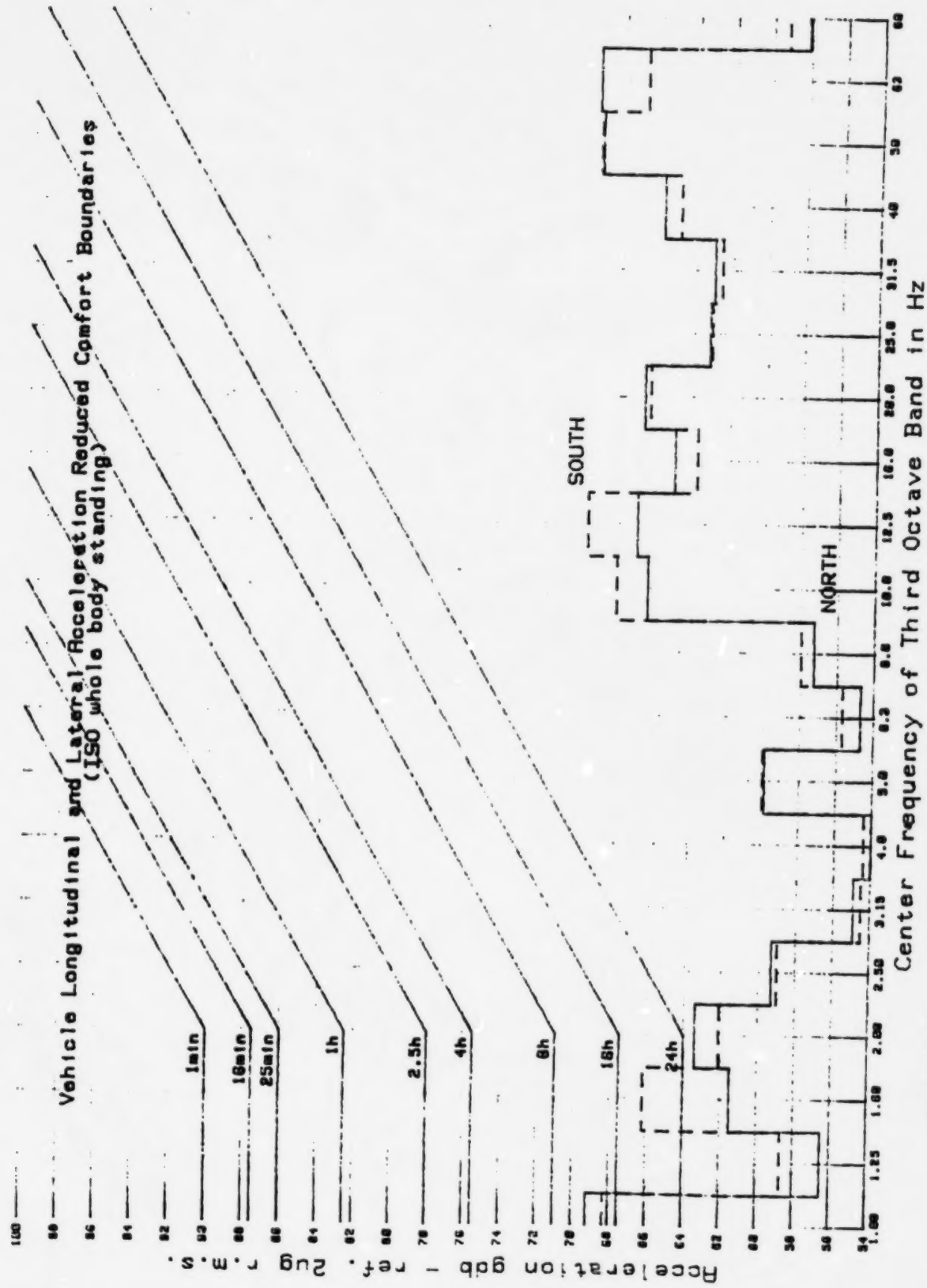
LONG. COACH CENTER -BREL75-50MPH-EMPTY

Figure 12

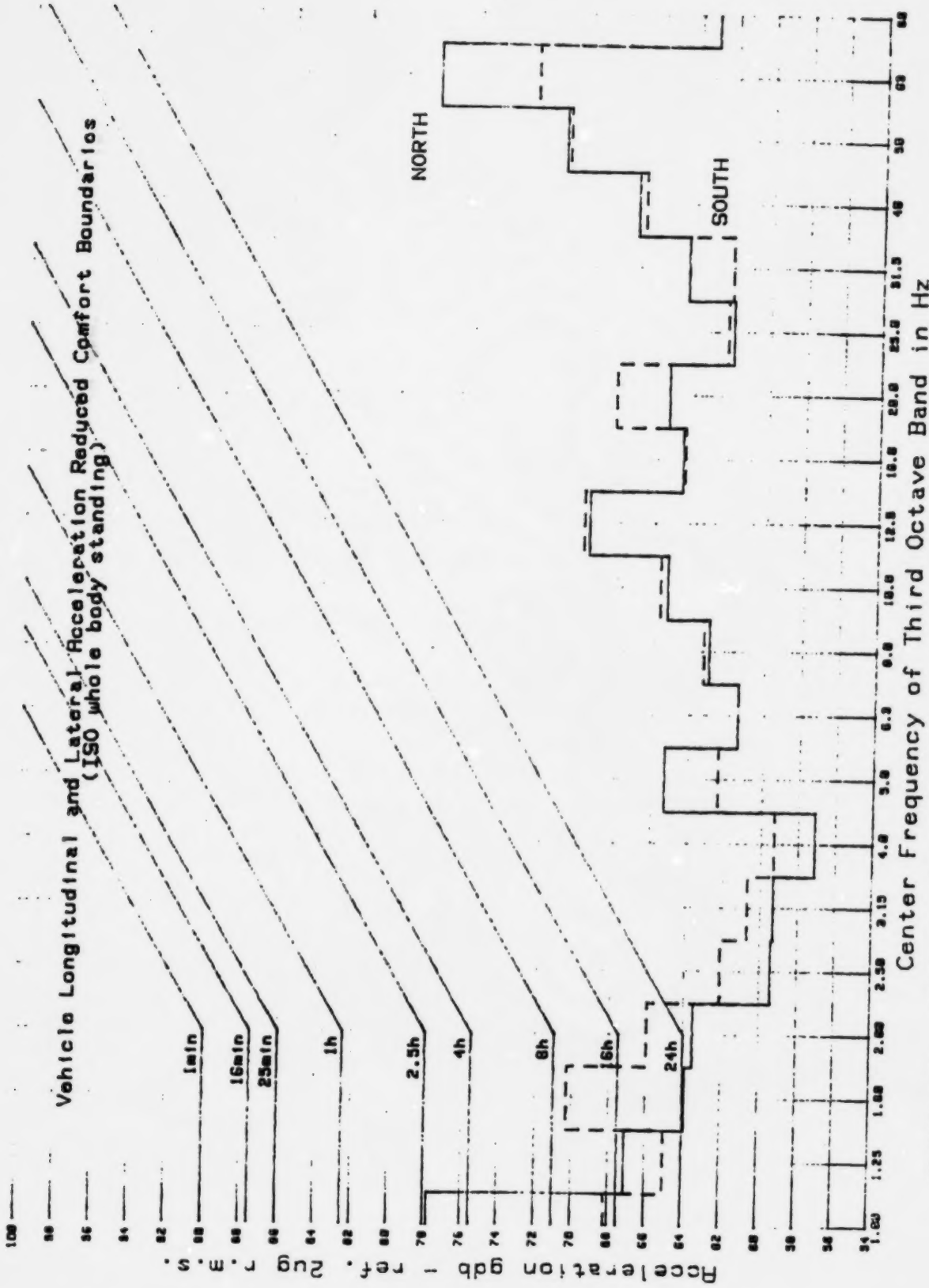


VERT. COACH CENTER -BREL75-50MPH-EMPTY

Figure 13

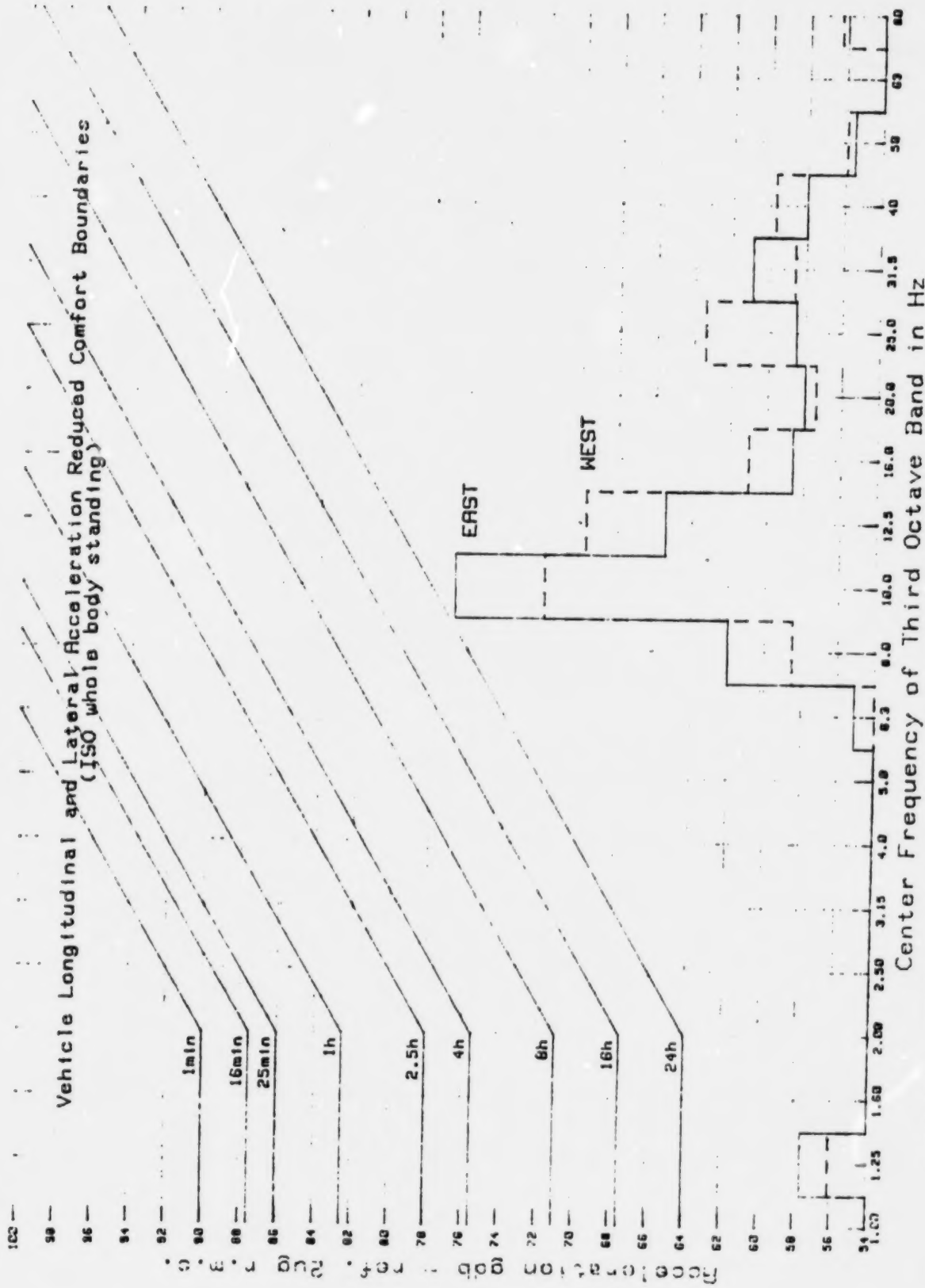


TRANS. COACH CENTER - BREL75-50MPH-EMPTY



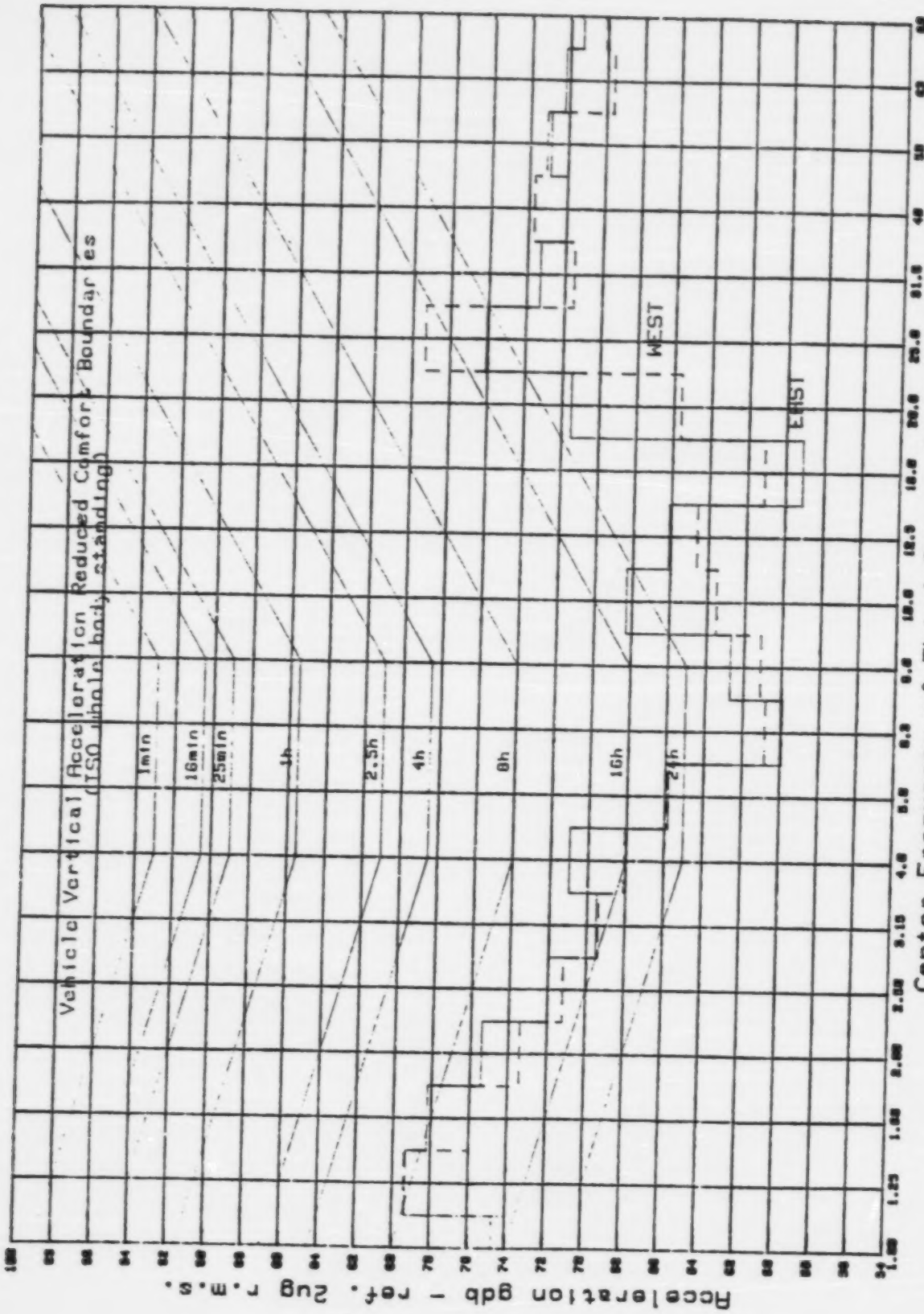
TRANS. AXLE CENTER A-END-BREL75-50MPH-EMPTY

Figure 15



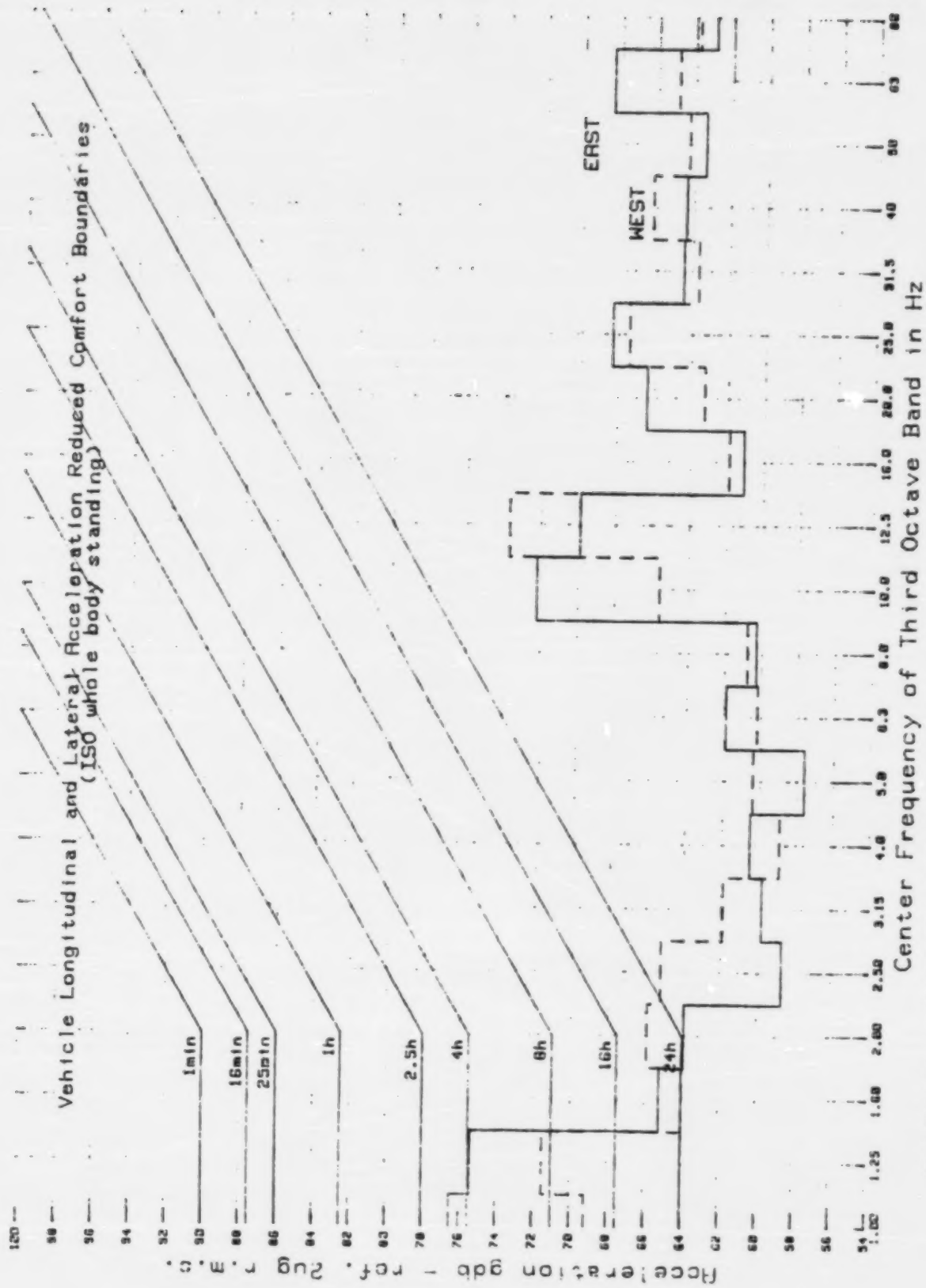
LONG. AXLE CENTER A-END-BREL75-60MPH-EMPTY

Figure 16



VERT. AXLE CENTER A-END-BREL75-60MPH-EMPTY

Figure 17



TRANS. AXLE CENTER A-END-BREL75-60MPH-EMPTY

3.2.2 Tracking Stability as Measured by Axle Mounted and Body Mounted Accelerometers

(a) Spectrum Analysis

The results of the acceleration survey are given in Figures 19 to 27.

Figure 19 compares the spectra from the transverse accelerometer at the "A" axle northbound and southbound at three different speeds near Chicoutimi. Figure 20 shows the spectra from the transverse accelerometer at the "B" axle is very similar and shows no fixed frequency buildup with speed such as occurs when a critical "hunting" speed has been reached. Figures 23 and 24 show similar results from the St-Hyacinthe region at higher speeds.

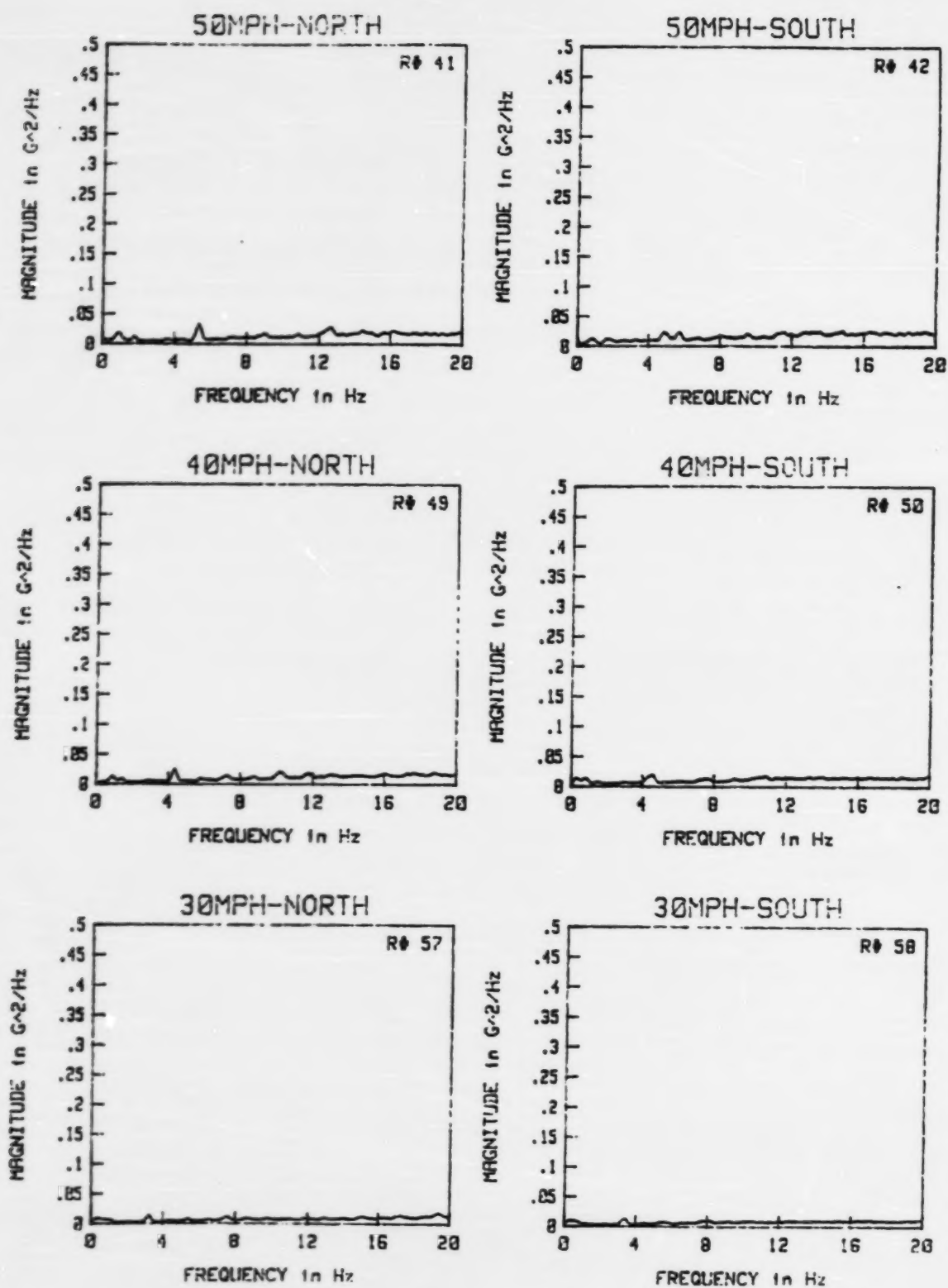
Figure 21 compares the spectra from the vertical accelerometer on the "B" axle left end northbound and southbound at three speeds near Chicoutimi. All these figures represent the car's input from the track (plus axle dynamics) in the "empty" condition. Figure 22 shows the spectra from the same accelerometers as presented in Figures 19, 20, and 21 at 50ph with the car in the "loaded" condition.

Figure 25 and 26 show comparable vertical spectra from the left ends of the "B" axle at higher speeds near St-Hyacinthe.

Figure 27 shows the longitudinal, vertical, and transverse vibration spectra inside the car at the "A" end. The original data (also used in the ISO ride quality assessment) was taken near St-Hyacinthe at 60 mph. These spectra show no sharp body resonances.

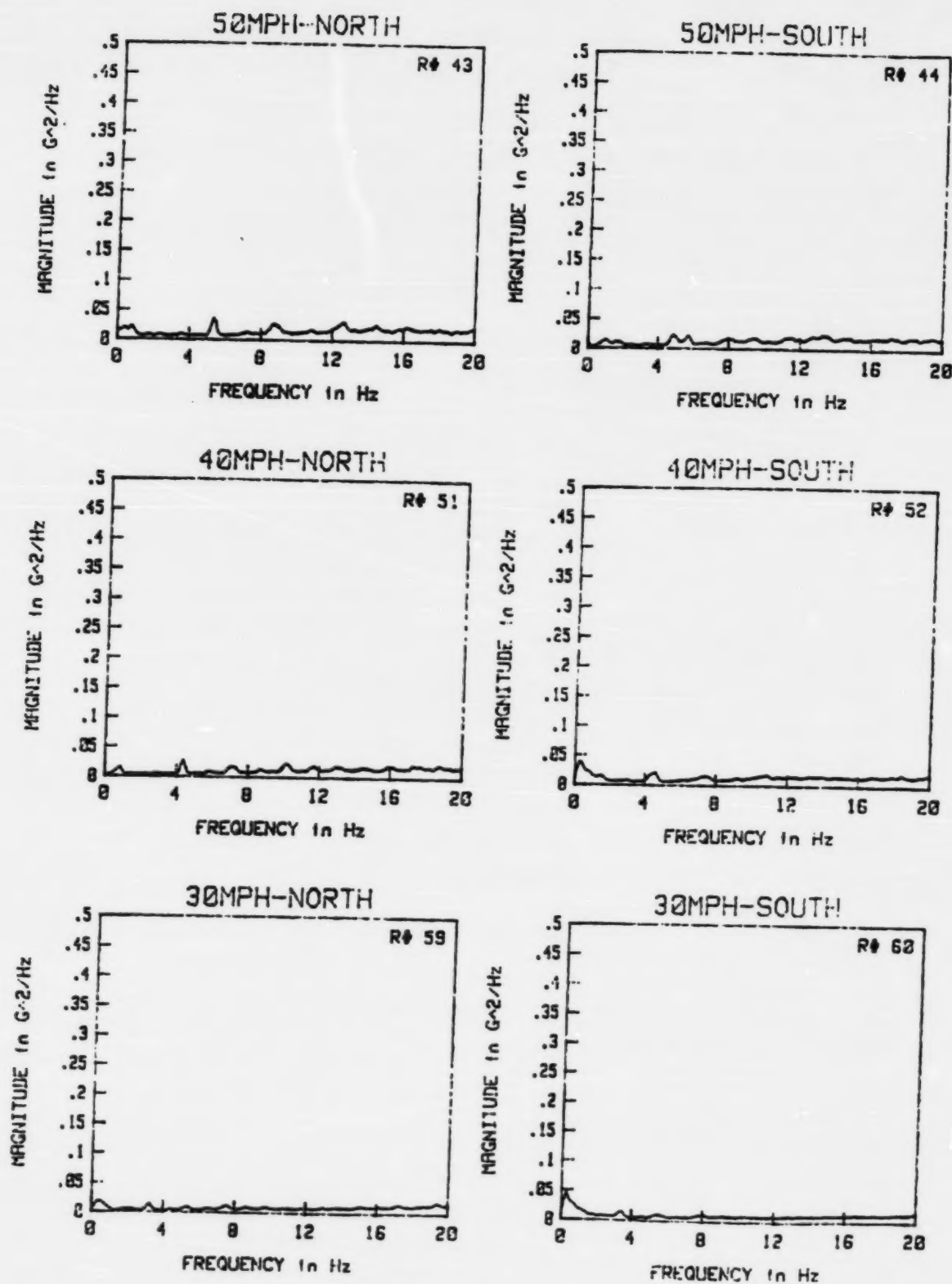
(b) Transient Response

A short section of time history of acceleration survey is shown in Figure 28.



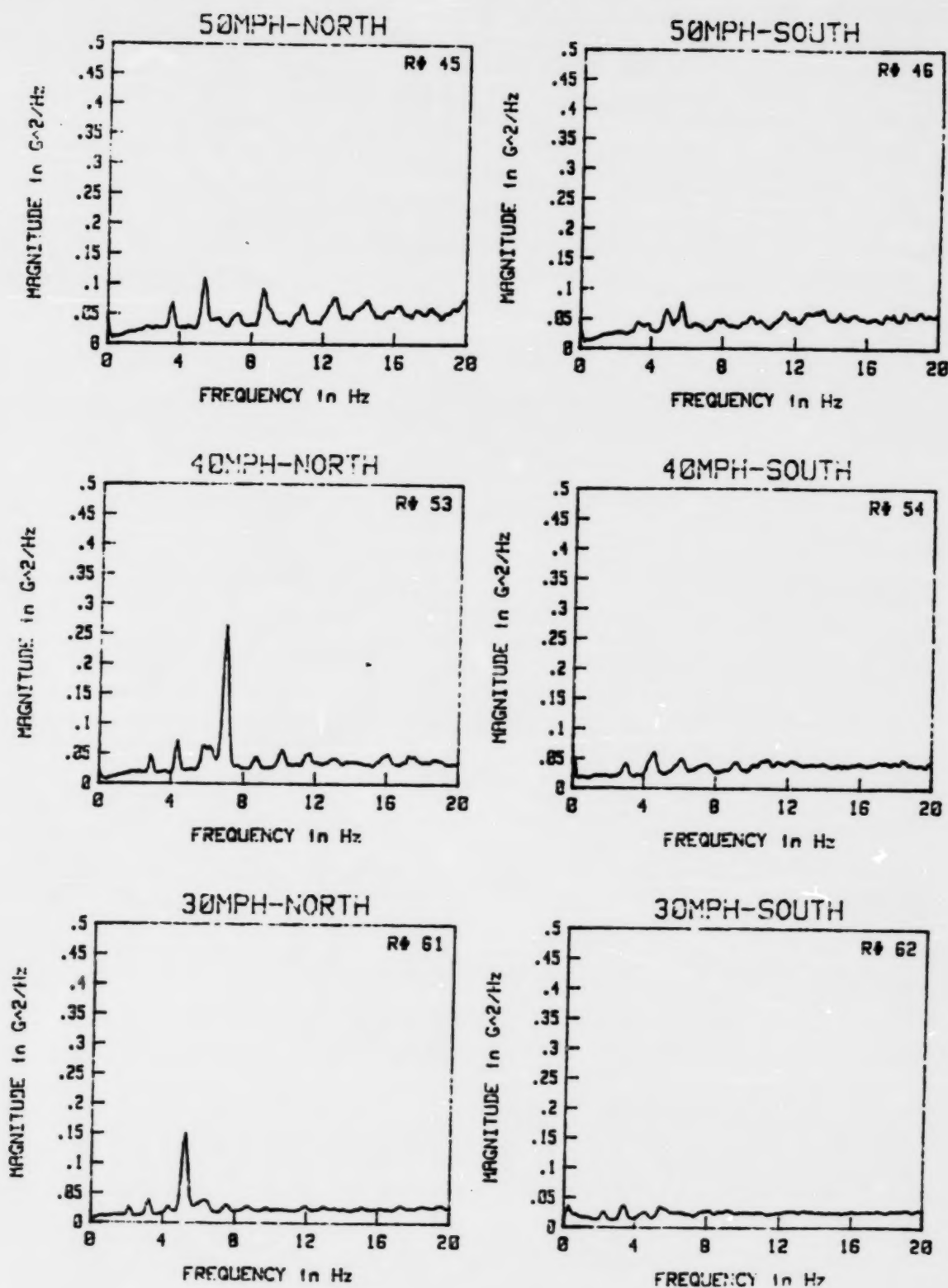
A-END-TRANS.-LEFT NORTH & SOUTH -EMPTY-

Figure 19 VIBRATION SPECTRA



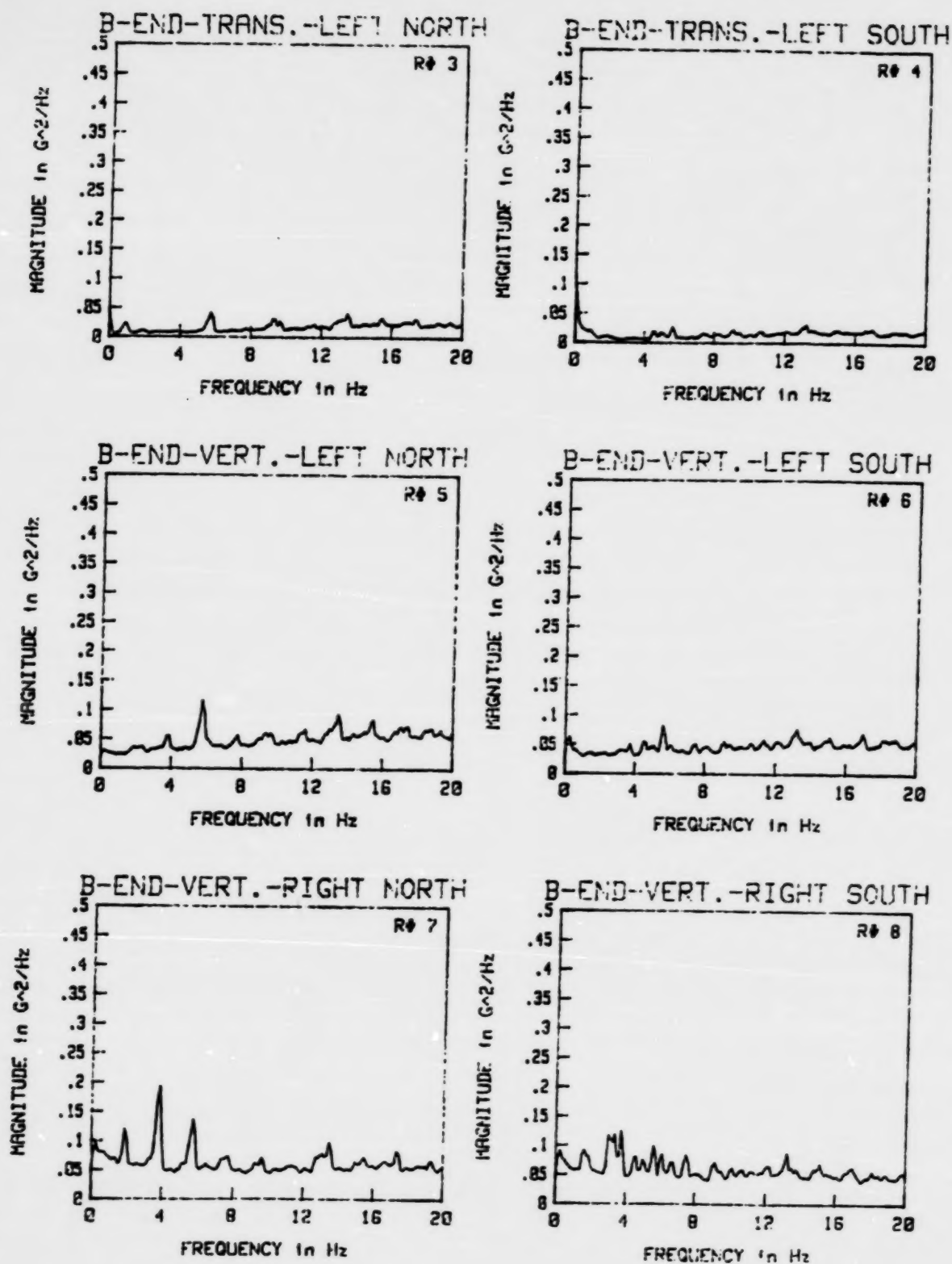
B-END-TRANS.-LEFT NORTH & SOUTH -EMPTY-

Figure 20 VIBRATION SPECTRA



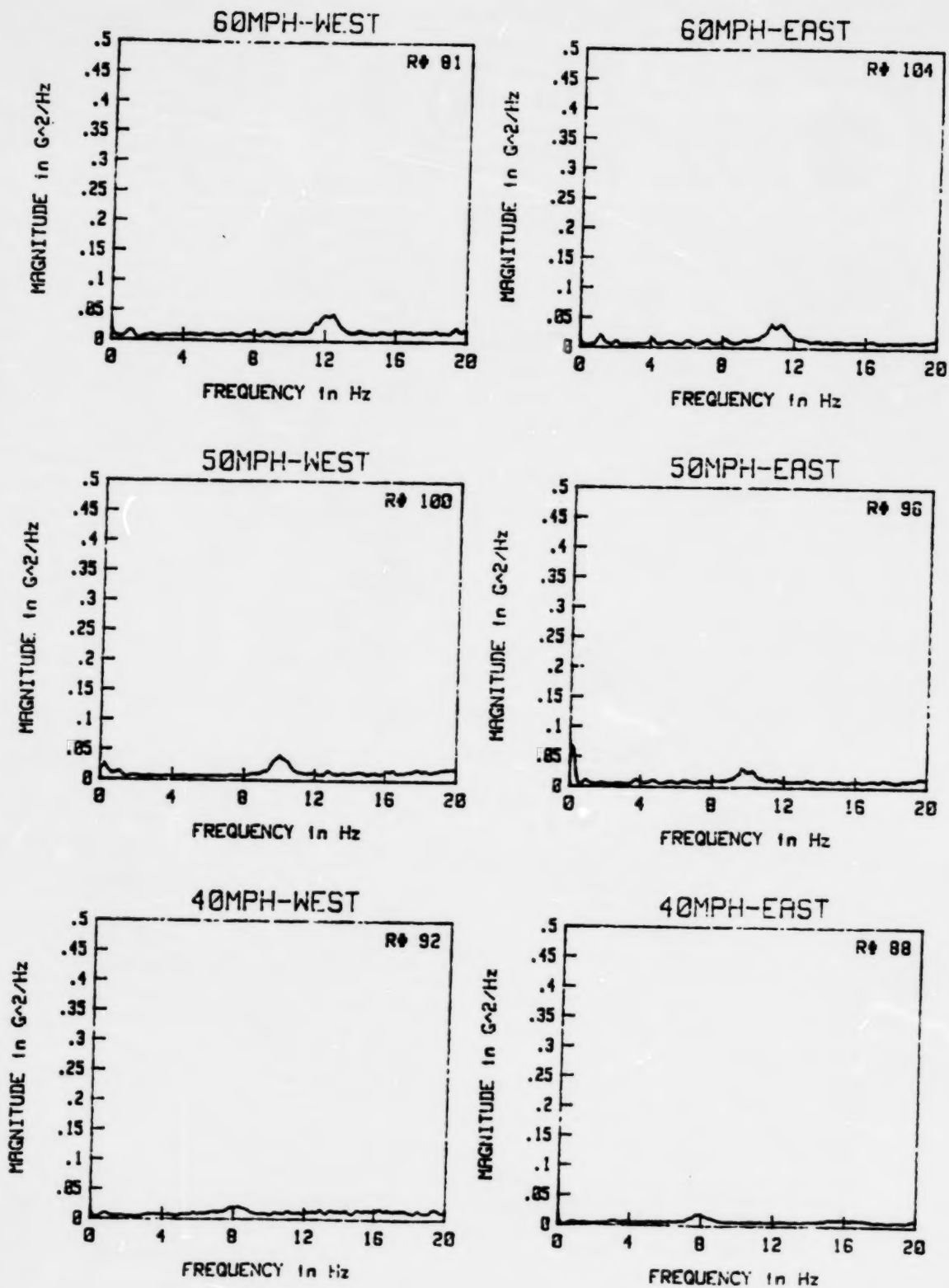
B-END-VERT.-LEFT NORTH & SOUTH -EMPTY-

Figure 21 VIBRATION SPECTRA

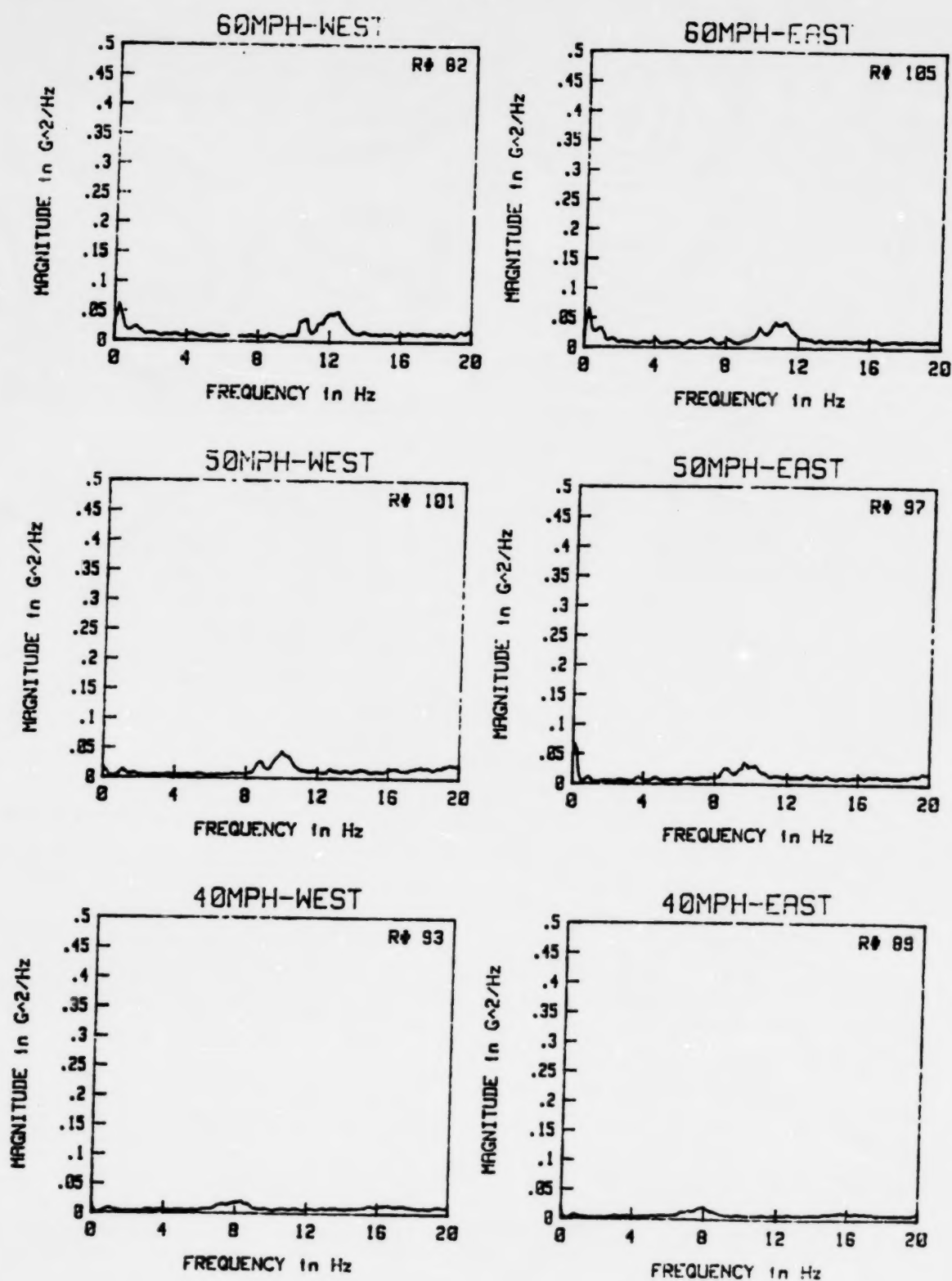


50MPH-LOADED NORTH & SOUTH

Figure 22

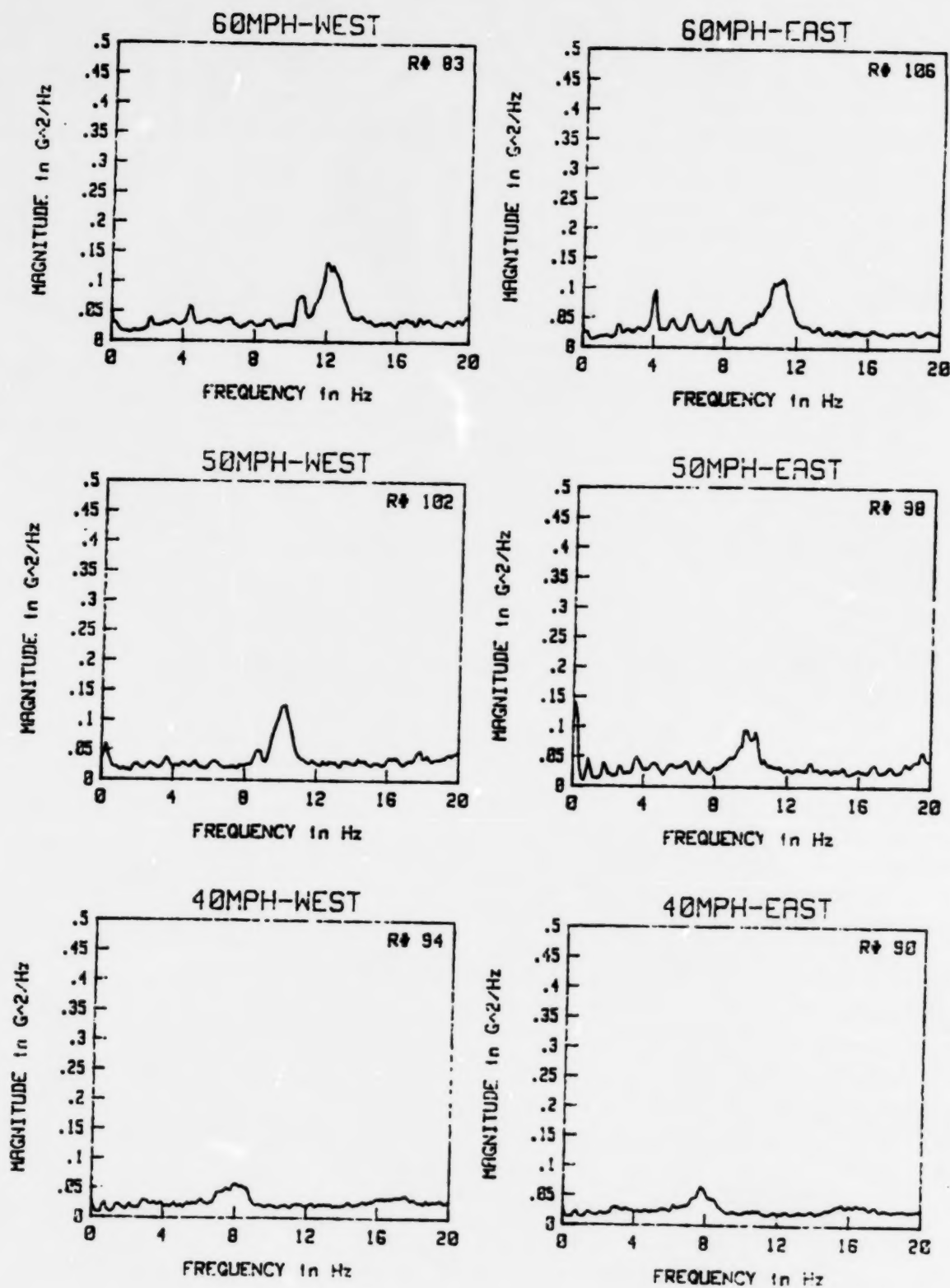


A-END-TRANS. WEST & EAST -EMPTY-

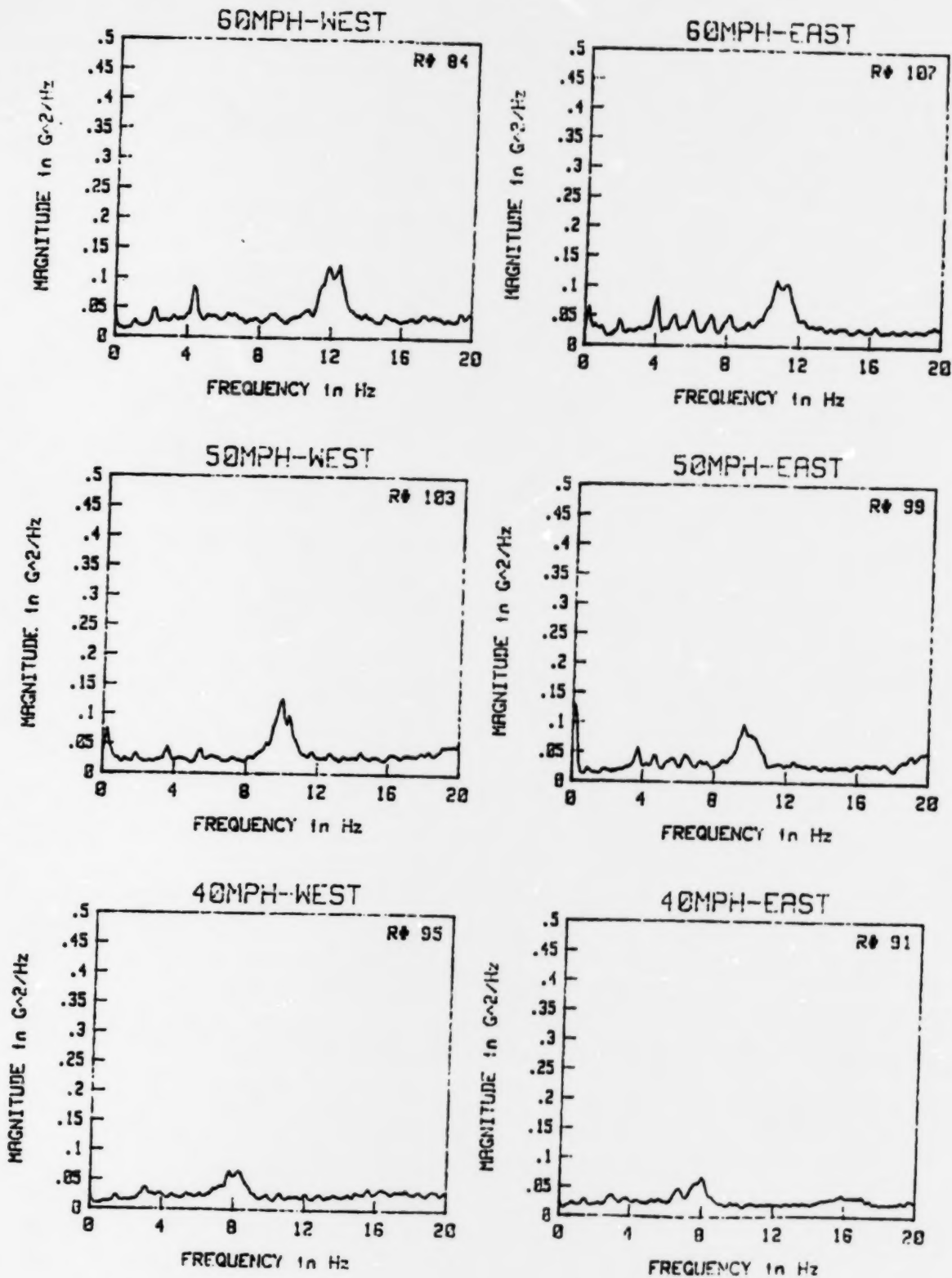


B-END-TRANS. WEST & EAST -EMPTY--

Figure 24

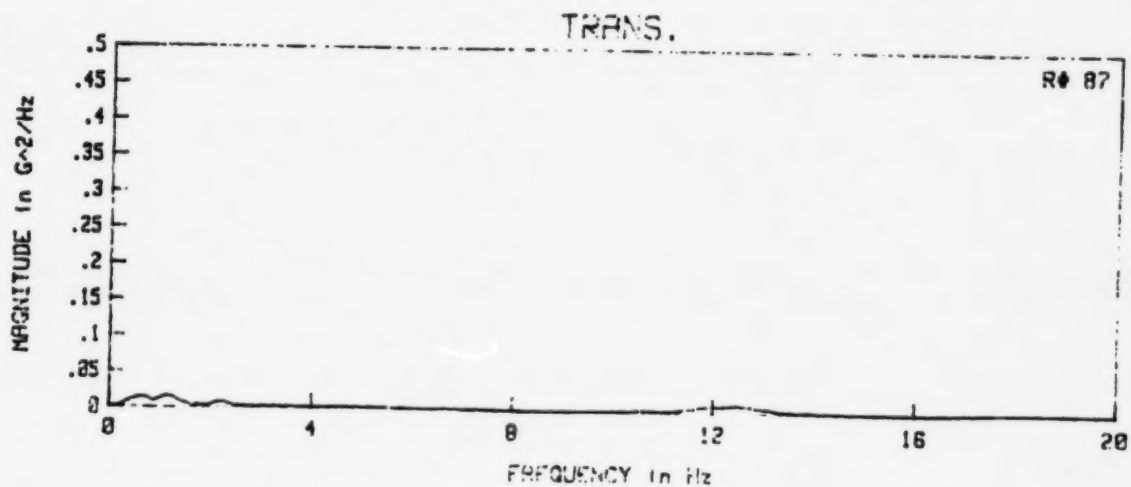
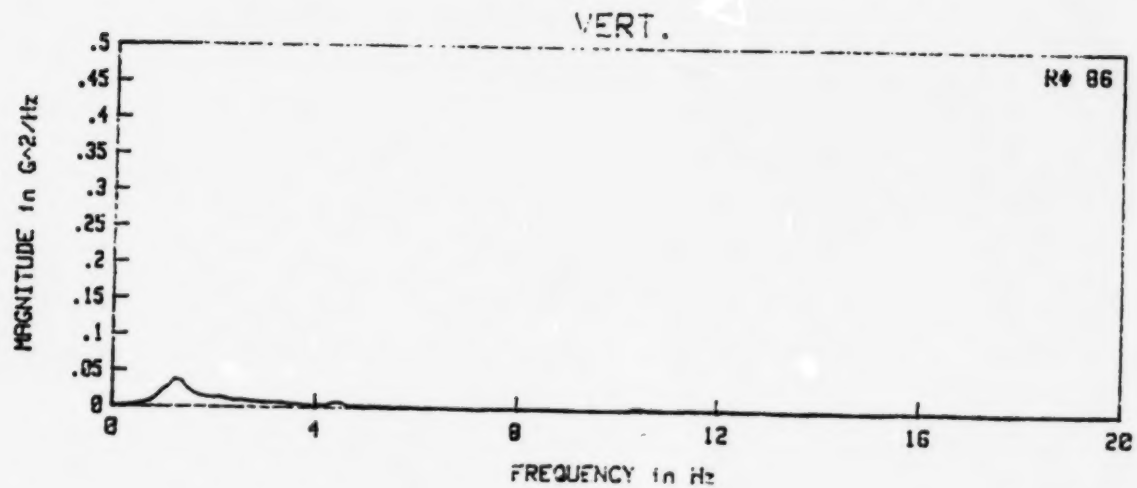
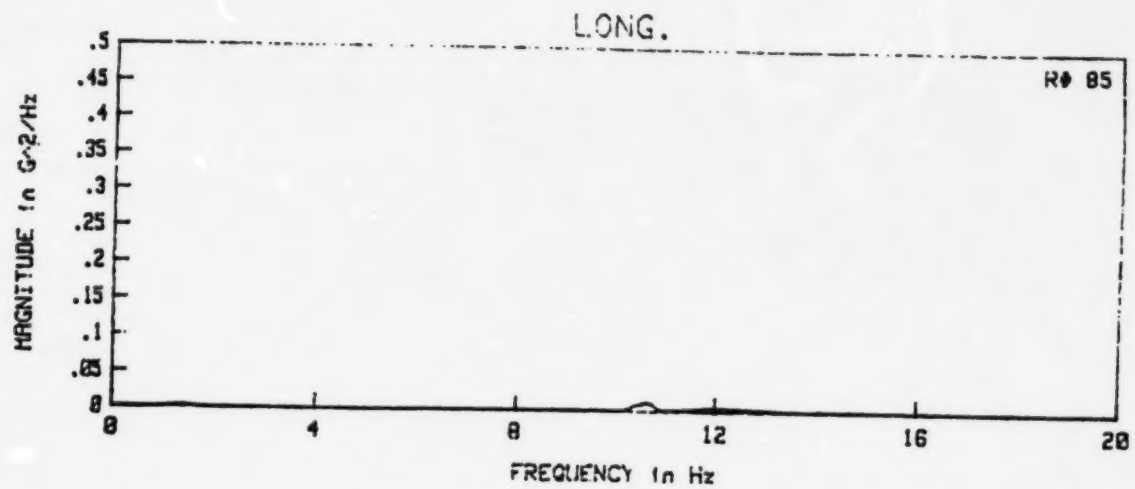


B-END-VERT.-LEFT WEST & EAST -EMPTY-



B-END-VERT.-RIGHT WEST & EAST -EMPTY-

Figure 26



60MPH-WEST-A-END-AXLE CENTER --EMPTY--

RAIL BUS ACCELERATION SURVEY SHOWING A TRANSIENT RESPONSE

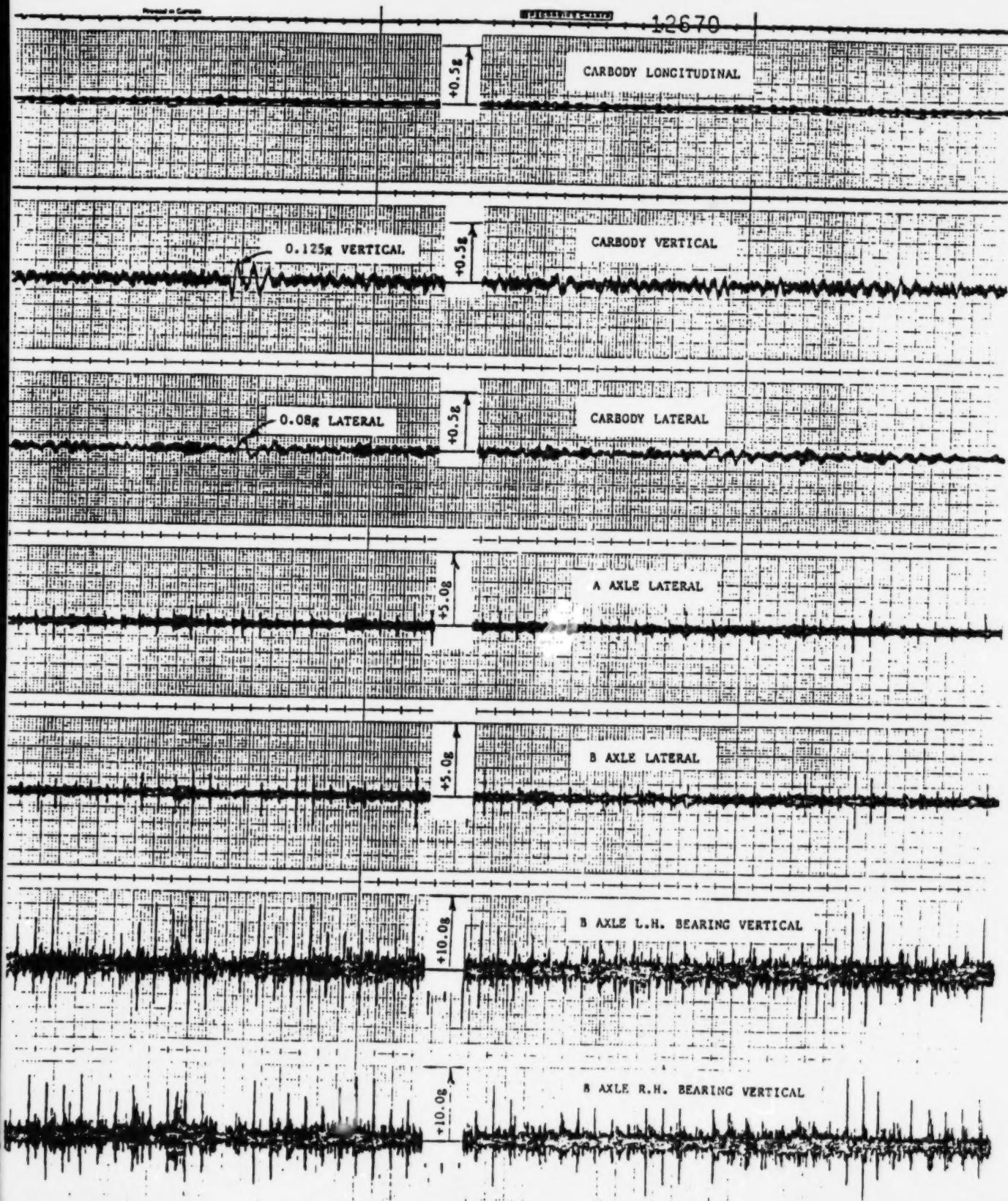


Figure 28 TIME HISTORY OF ACCELERATIONS

3.3 Curving performance results are given in tabular form with regard to track loads measured (Table 5) and L/V ratio (Table 6).

4° Curve Mile, 156, Lac St-Jean Region
Positive Readings Towards Field Side
Negative Readings Towards Gauge Side

All Readings in KLBS

Speed (mph) Dir.	HRL/LA	HRL/TA	LRL /LA	LRL/TA	HRV /LA	HRV /TA	LRV /LA	LRV /TA
40N	-1.5/2.5	0.5	2.3	-0.7/0.7	21.5	16.5	15.0	20.0
40N	-1.5/2.5	0.5	2.5	-0.7/0.5	22.5	18.5	15.5	19.0
40N	-2.1/2.4	0.4	2.4	-0.5/0.5	21.8	17.8	15.5	19.0
30N	-1.0/3.1	-0.4	4.3	1.1	19.0	16.5	15.0	19.0
30N	-1.3/2.4	-0.4	3.8	1.1	19.5	15.5	16.0	20.0
31N	-1.4/2.1	-0.4	3.5	1.1	19.2	16.2	15.5	18.5
21N	-1.6/1.5	-0.8	4.4	1.1	17.3	16.3	17.7	19.7
20N	-1.5/1.5	-0.8	4.1	1.1	17.8	16.3	17.6	19.8
21N	-2.0/1.8	-0.8	3.6	1.1	17.5	16.5	17.6	19.1
29S	2.0/-1.0	0.3/-0.5	4.2	1.6	16.2	16.5	21.2	20.2
32S	2.3/-1.3	0.4/-0.6	4.5	1.5	17.8	17.0	19.8	19.4
32S	1.8/-1.3	0.3/-0.3	4.5	1.3	17.8	17.6	19.0	19.0
28S	3.6/-1.0	-0.6	7.0	1.1	16.0	16.5	16.0	15.0
32S	2.4/-1.1	-0.8	4.3	1.0	17.0	17.0	19.5	18.5
30S	2.8/-1.0	-1.0	5.0	1.1	16.8	17.0	19.5	19.0
18S	3.1/-0.8	-1.4	5.6	1.4	15.5	16.0	20.0	25.0
20S	2.5/-0.9	-1.3	4.9	1.4	15.8	15.2	20.0	19.8
20S	2.4/-0.9	-1.5	5.0	1.2	15.7	15.7	20.5	19.5

HRL - High Rail Lateral
LRV - Low Rail Vertical
LA - Leading Axle
TA - Trailing Axle

TABLE 5 CURVING FORCES ON BRE-LEYLAND RAILBUS "LOADED"

4° Curve, Mile 156

Lac St-Jean Region

HR /LA	HR /TA	LR /LA	LR /TA	Speed (mph) Dir.
0.12	0.03	0.15	0.04	40N
0.11	0.03	0.16	0.03	40N
0.11	0.02	0.15	0.03	40N
0.16	-0.02	0.29	0.06	30N
0.12	-0.03	0.24	0.06	30N
0.11	-0.02	0.23	0.06	31N
0.09	-0.05	0.25	0.06	21N
0.08	-0.05	0.23	0.06	20N
0.10	-0.05	0.20	0.06	21N
0.12	-0.03	0.20	0.08	29S
0.13	-0.04	0.23	0.08	32S
0.10	-0.02	0.24	0.07	32S
0.23	-0.04	0.44	0.07	28S
0.14	-0.05	0.22	0.05	32S
0.17	-0.06	0.26	0.06	30S
0.20	-0.09	0.27	0.06	18S
0.16	-0.09	0.25	0.07	20S
0.15	-0.10	0.24	0.06	20S

L/V - Lateral/Vertical Ratio

HR - High Rail

LR - Low Rail

LA - Leading Axle

TA - Trailing Axle

N - North Bound

S - South Bound

TABLE 6 CURVING L/V RATIOS BRE-LEYLAND RAILBUS - "LOADED"

3.4 Acceleration performance is presented in tabular form in Table 7 and graphically in Figure 29.

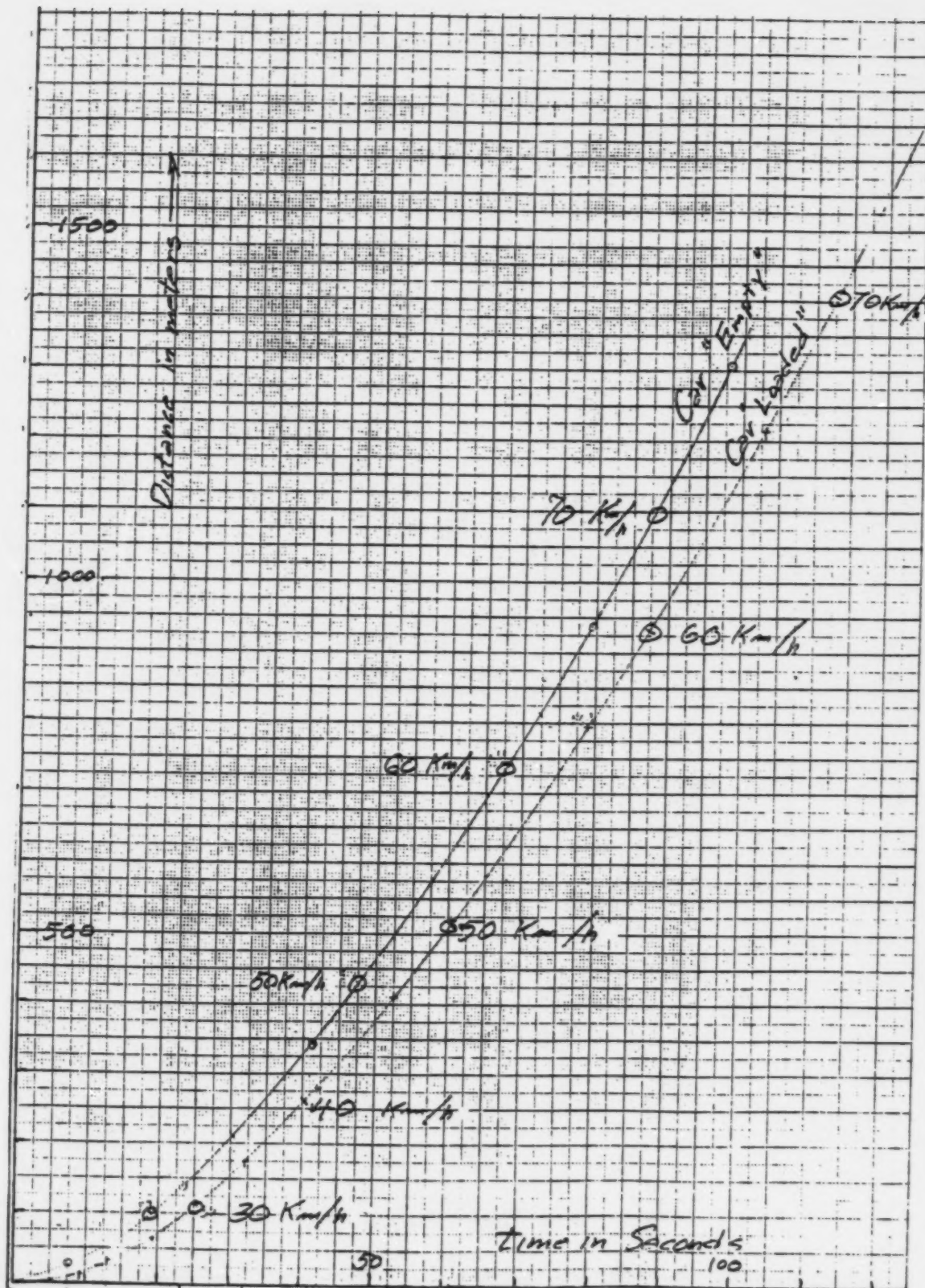
SPEED MPH	SPEED KM/H	TIME SECS	DIST. METRES
10	16.1	7.6	26.36
20	32.2	23.2	140.56
30	48.3	41.24	343.87
40	64.4	79.2	937.5
45	72.4	98.2	1306.5

TABLE 7 (a) ACCELERATION "EMPTY"

SPEED MPH	SPEED KM/H	TIME SECS	DIST. METRES
5	8	8.2	13.8
10	16.1	12.84	32.63
15	24.1	18.64	64.8
20	32.2	32.16	174.5
25	40.2	42.12	278.9
30	48.3	52.48	410.1
35	56.3	79.0	795.9
40	64.4	103.36	1215.8
45	72.4	128.56	1705.0

TABLE 7 (b) ACCELERATION "LOADED"

Fig. 29 Distance vs Time During Acceleration



3.5 Braking Distances

Braking distances measured are shown in Table 8.

SPEED KM/H	DIREC- TION	TIME SECS	DIST. METRES	AVG. DESC. M/S ²
32.0	north	11.9	58.0	0.75
48.3	north	15.9	106.7	0.84
62.8	north	21.7	187.8	0.80
32.0	south	12.6	66.0	0.71
48.3	south	16.4	119.5	0.82
64.4	south	22.0	195.4	0.81

TABLE 8 (a) BRAKING PERFORMANCE (EMPTY)

Due to time constraints and darkness, only two loaded braking tests were made.

48.3	north	21.5	112.1	0.62
64.4	north	25.5	198.1	0.68

TABLE 8 (b) BRAKING PERFORMANCE (LOADED)

Note: The difference in stopping distances between north and south bound runs is possibly due to the air brake reservoir being at one end of the vehicle: when the brakes are applied at the other end, there is a slight time lag.

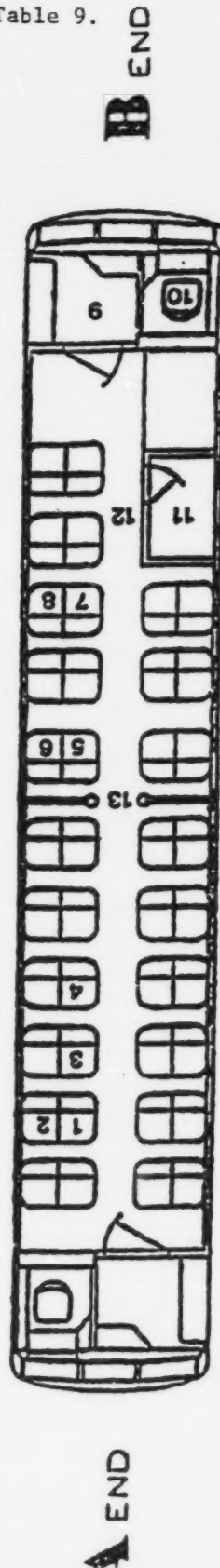
3.6 Lighting Survey

Lighting survey results are shown in Table 9.

TABLE 9 LIGHTING SURVEY

LOCATION	1	2	3	4	5	6	7	8	9	10	11	12L	12H	13L	13H
FOOT/ CANDLES	17.4	11.1	13.3	13.5	19.1	15.4	14.0	11.0	19.7	3.3	9.3	6.6	78.0	7.2	78.5
LUX	187	119	143	145	206	166	151	118	212	36	100	71	839	77	845

Readings at positions 1 to 11 were taken at lap height.
Readings at positions 12 and 13 were taken at floor level (L)
and at eye level (H)



4.0 CONCLUSIONS

Throughout the entire test program, the BRE-Leyland 141 railbus behaved well and exhibited no vices. All signals were activated regardless of tested speeds or direction of travel.

There was no evidence of instability at the speeds achieved, i.e. 60 mph (96.5 km/h), and the ride was acceptable and well within the boundaries associated with railbus trip times.

APPENDIX I

INTERIOR NOISE MEASUREMENTS ON A BRE-LEYLAND
141 LIGHT DIESEL RAILCAR

J.A. HAMMER

March 1986

CONTENTS

SUMMARY

LIST OF ILLUSTRATIONS

- 1.0 INTRODUCTION
- 2.0 INSTRUMENTATION AND MEASUREMENT PROCEDURE
- 3.0 RESULTS AND DISCUSSION
- 4.0 CONCLUSIONS

SUMMARY

The results of noise measurements carried out inside a BRE-Leyland railbus near Jonquière, Quebec, are presented. The levels in the passenger area at speeds of 60-75 km/hr were in the range of 63-67 dBA. The levels were higher beside the side entry doors and in the driver's compartment. The measurements indicated that the operation of auxiliary floor heaters caused a considerable increase in interior noise levels.

ILLUSTRATIONS

Figure 1 Instrument Setup for Recording and Measuring Sound Levels

- 2 Block Diagram of the Analysis System
- 3 Location of the Measurement Positions and Heating Systems
- 4 A-Weighted Sound Levels Inside the Railbus
- 5 Linear Sound Levels at Position 1 at a Speed of 60-75 km/hr
- 6 Linear Sound Levels at Position 2 at a Speed of 60-75 km/hr
- 7 Linear Sound Levels at Position 3 at a Speed of 60-75 km/hr
- 8 Linear Sound Levels at Position 4 at a Speed of 60-75 km/hr
- 9 Linear Sound Levels at Position 5 at a Speed of 60-75 km/hr
- 10 Linear Sound Levels at Position 6 at a Speed of 60-75 km/hr
- 11 Linear Sound Levels at Position 7 at a Speed of 60-75 km/hr
- 12 Linear Sound Levels at Position 8 at a Speed of 40-50 km/hr
- 13 Linear Sound Levels at Position 1 During the Use of External Air Horns
- 14 Linear Sound Levels at Position 2 During the Use of External Air Horns

1.0 INTRODUCTION

The Transport Development Centre is conducting an engineering assessment of the BRE-Leyland 141 light diesel rail car for use in Canada with the assistance of the National Research Council of Canada. As part of this assessment, the Noise and Vibration Group of the Division of Mechanical Engineering was asked to perform noise measurements inside the vehicle. This report presents the results of noise measurements made during runs in the Jonqui re area, Quebec, on March 1st and 2nd, 1986.

2.0 INSTRUMENTATION AND MEASUREMENT PROCEDURE

The noise measurements were carried out over the duration of two days, March 1 and 2. The objective of the measurements was to produce a survey of noise levels throughout the interior of the railbus and identify any major sources of noise. The following instruments were used:

- 1 Impulse Prediction Sound Level Meter
Br el and Kjaer Type 2209
- 1 Condenser Microphone, 1/2" Br el and Kjaer Type 4133
- 1 Flexible Microphone Extension
- 1 FM Tape Recorder, Br el and Kjaer Type 7003
- 1 Sony Oscilloscope, Model 326

Nine measurement positions were chosen throughout the bus as shown in Figure 3 (labelled as P1 to P9).

The microphone was mounted at a height of approximately 130 cm above the floor. This height was chosen as a compromise between the ear level of a seated passenger (approx. 110 cm) and that of a standing passenger (approx. 150 cm). The results of the level survey reported in Figure 4 were obtained at the same time as tape recordings were made using a tripod to hold the sound level meter. Other measurements for the sound level survey were done with the meter held by hand. The set up for recording is shown in Figure 1.

The levels recorded on tape were analysed in the Laboratory using a Br el and Kjaer one third octave real-time analyser (type 2131) in conjunction with a desktop computer and plotter as shown in Figure 2.

3.0 RESULTS/DISCUSSION

The sound measurements were made inside the railbus at speeds between 60 and 75 km per hour over a variety of track conditions, including grades, curves, and straight sections. A full passenger load was simulated in the bus through the use of concrete blocks between the seats. Most of the measurements reported were made with the main heating system operating since the outdoor temperatures were around -10°C . Some measurements were also made with the floor mounted auxiliary heaters running in order to observe the effect on overall levels. Figure 3 shows the location of the auxiliary heaters and ceiling heating ducts throughout the bus. The figure also shows a door in each end separating the passengers from the entry areas adjacent to the side entry doors. These doors were kept closed during recordings and level measurements.

The term "A-Weighting" refers to the process of weighting sound pressure levels so that they represent the sound as humans would hear it. Figure 9 shows a sound pressure level survey in dBA (decibels, A-weighted) measured throughout the bus. These levels were measured when the railbus was travelling at speeds of 60 to 75 km/hr. The levels were generally in the range 64-66 dBA throughout the passenger area. The increase of 1-2 dBA at Position 4 could have been the result of fans in the ceiling heating ducts. There did not appear to be any difference in the levels measured at the centre seats (P5) as compared to those measured at the ends of the bus near the wheels (P3 and P7). Levels at Position 2 were on the average 5 dBA higher than the passenger area, probably as a result of external noise leaking in through the side door. Position 1 showed levels in the range 65-70 dBA. Positions 8 and 9 had the same levels as Positions 1 and 2.

The use of auxiliary heater blowers located under some of the seats caused levels to increase up to 10 dBA in the passenger area. Although no recordings of this noise were made, it could be described as broadband noise since it contained no distinct tones.

The use of the external air horns at crossings resulted in momentary level increases to 95 dBA in the conductor's area and passenger area at that end of the bus.

The overall sound levels in the car are the result of a combination of many different noise sources. At speeds of 60 to 75 km/hr, the impact of the vehicle wheels hitting joints in the tracks would be in the frequency range of 2 Hz to 10 Hz. The sound of the wheels rolling along the tracks would produce noise spread over a wider range of higher frequencies. The diesel motor, generator, DC to AC inverter, heater blowers, and other mechanical and electrical equipment all contribute in various degrees and frequencies to the overall levels throughout the railbus.

Recorded levels were processed using a one third octave band frequency analyser to identify sources contributing to the overall levels. The results of these analyses are presented in Figures 5 to 14 in the form of linear spectra. A linear spectrum presents the unmodified sound pressure levels rather than the levels as humans would hear them. This format is useful in evaluating the distribution of acoustic energy over the frequency spectrum.

Figures 5 to 14 show spectra dominated by noise below 100 Hz. The dynamic range of the tape recorder was 40 dB and as a result the low levels above 1000 Hz may have been influenced by instrumentation noise and hence are unreliable.

In Figures 1 to 11 the spectra for Positions 1 to 7 at speeds of 60 to 75 km/hr are shown. Two peaks are evident, one at 10 to 12.5 Hz and one at 63 Hz.

The peak at 10-12 Hz has generally the same level throughout the car with the exception of Position 2 [Figure 6] where it is nearly 5 dB higher. This peak may be related to the noise produced by the impact of the vehicle wheels on joints between the rails. This could be supported by the increased level at Position 2 where external noise was coming in around the side doors.

The peak at 63 Hz was prominent for Positions 3 to 6 [Figures 7 to 10]. These positions were directly over the diesel motor, gearbox and generator and also in the area of the ceiling heater ducts. The frequency of the alternating current for the overhead fluorescent lights and other AC devices could also contribute in this range. The peak could have been related to any one of these sources. A peak is evident at 80 Hz for Position 1 ([Figure 5] where communications equipment and a heating system were being used.

Figure 12 shows sound levels measured at Position 8 at a speed of approximately 45 km/hr. The recording was made as the bus was entering rougher sections of track in Jonqui re yards, and hence shows higher levels from wheel impacts in the range 1.6 to 4 Hz.

Figures 13 and 14 show spectra for Positions 1 and 2 during the use of the external air horns at a speed of 60 km/hr. The peaks at 315 Hz and 800 Hz are related to the horn's tones.

In general the spectra measured throughout the railbus showed similar overall characteristics, being dominated by road band noise below 100 Hz.

4.0 CONCLUSIONS

At speeds of 60-75 km/hr the noise level in the passenger area were generally in the range of 64-66 dBA throughout the bus. The area beside the side entry doors had an average noise level 5 dBA higher than the passenger area, or 70 dBA. The noise level in the driver's compartment was in the range of 65 to 70 dBA.

The use of floor mounted auxiliary heaters increased the levels in the passenger area by up to 10 dBA.

The use of the external air horns caused the levels to rise momentarily by 25-30 dBA in that end of the railbus.

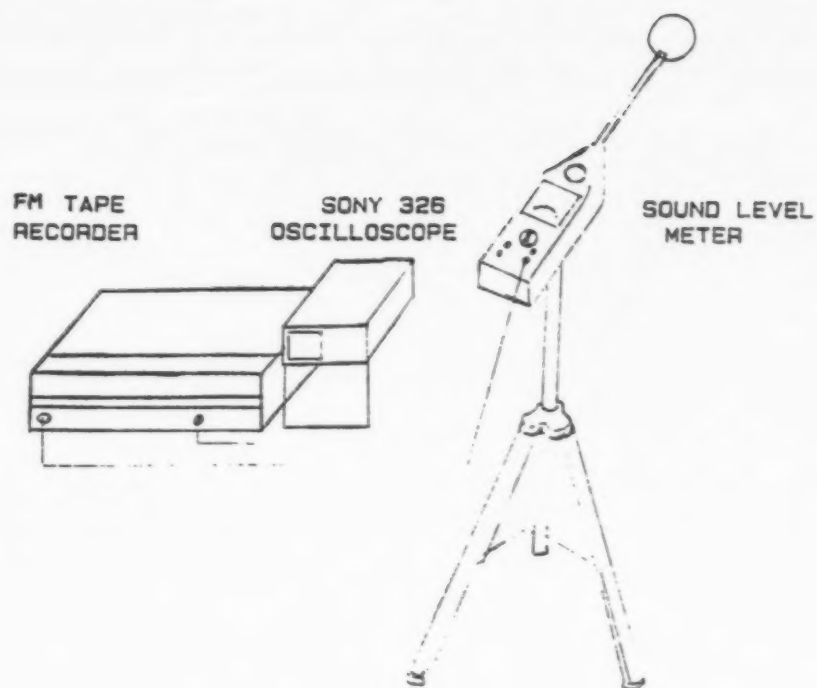


Fig. 1. Instrument Setup for Recording and Measuring Sound Levels

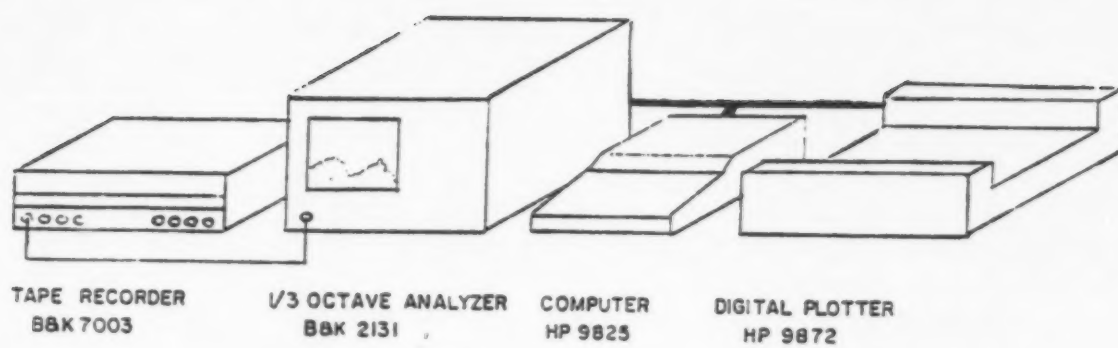


Figure2 : Block Diagram of the Analysis System

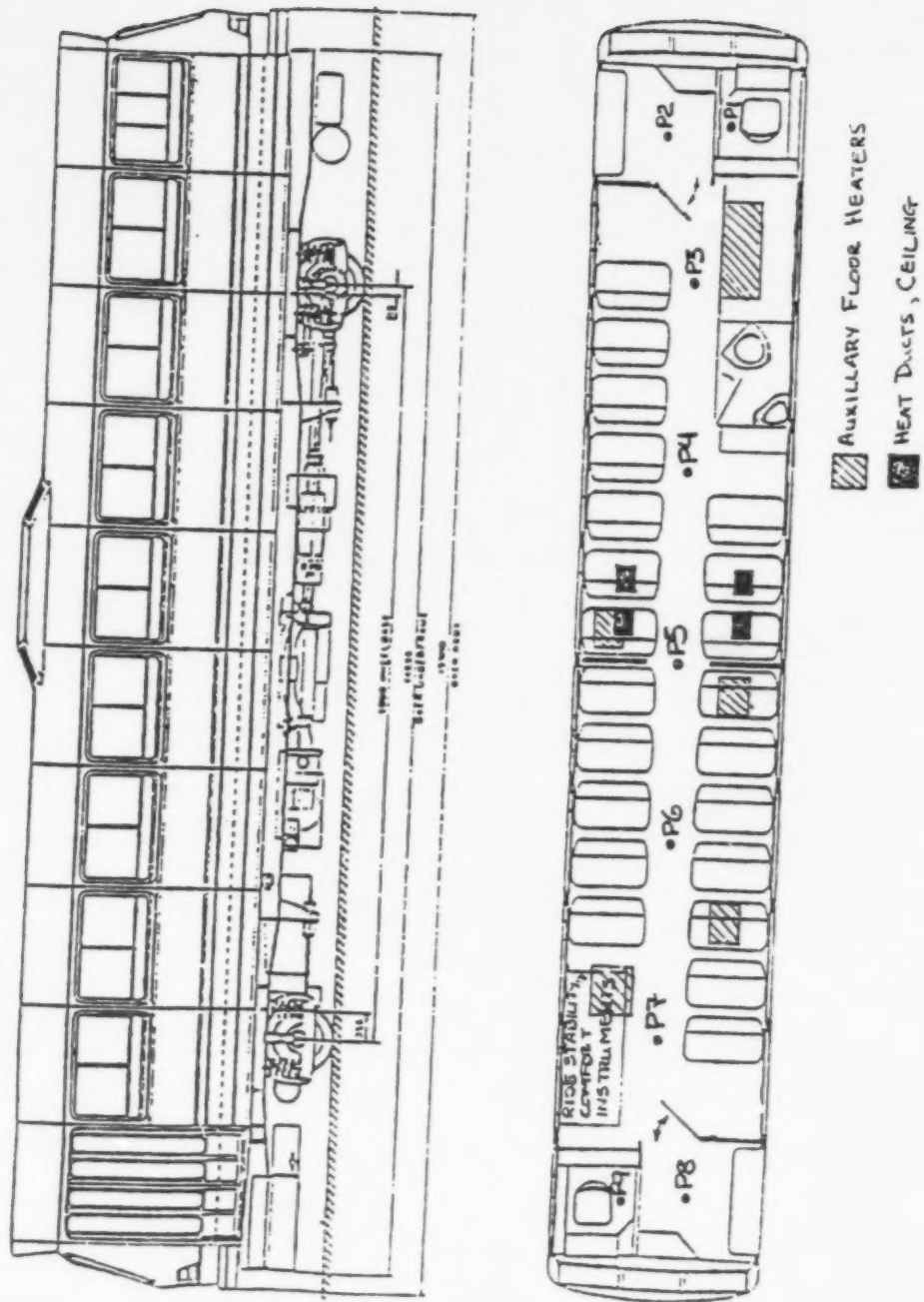


Fig. 3. Location of the Measurement Positions and Heating Systems

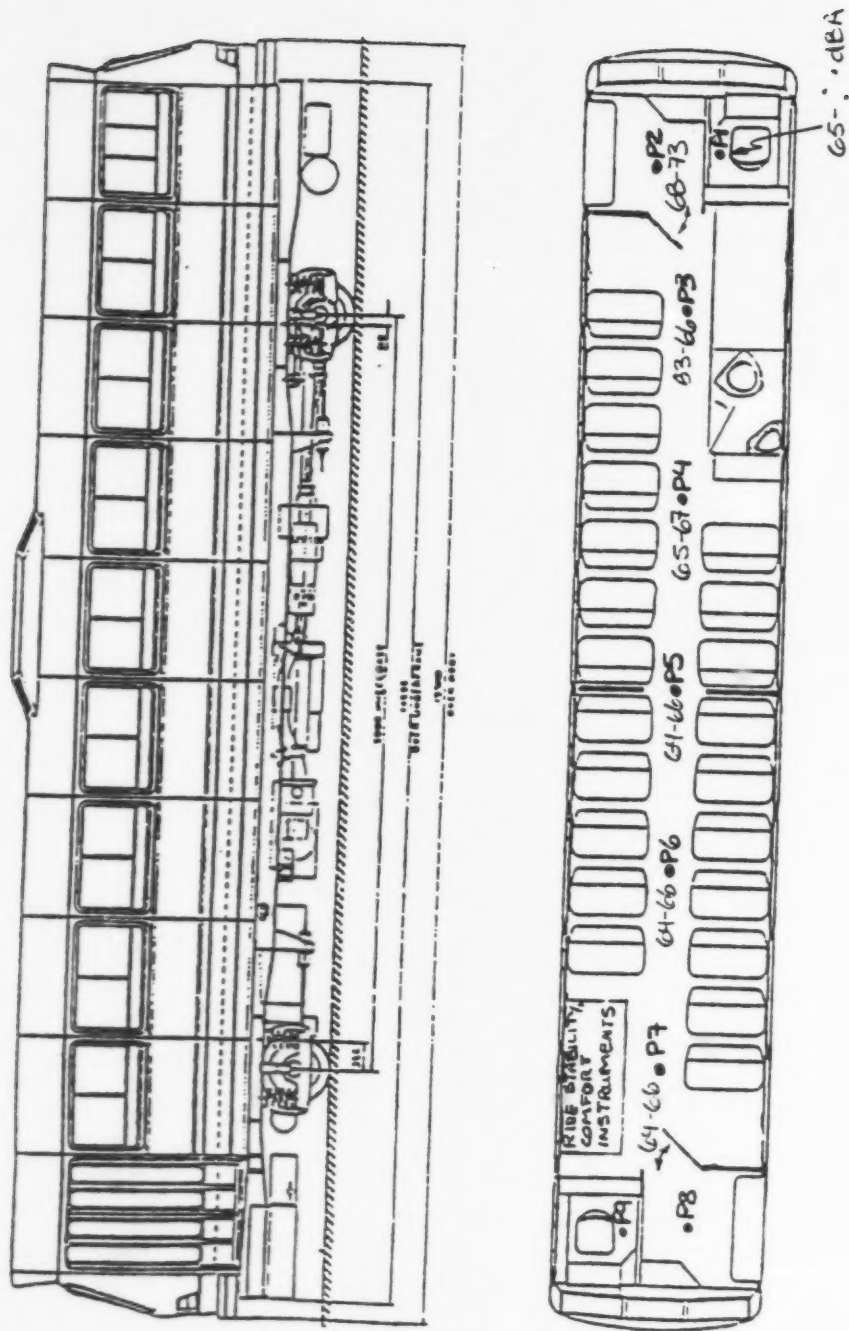


Fig. 4. A-weighted Sound Levels Inside the Railbus

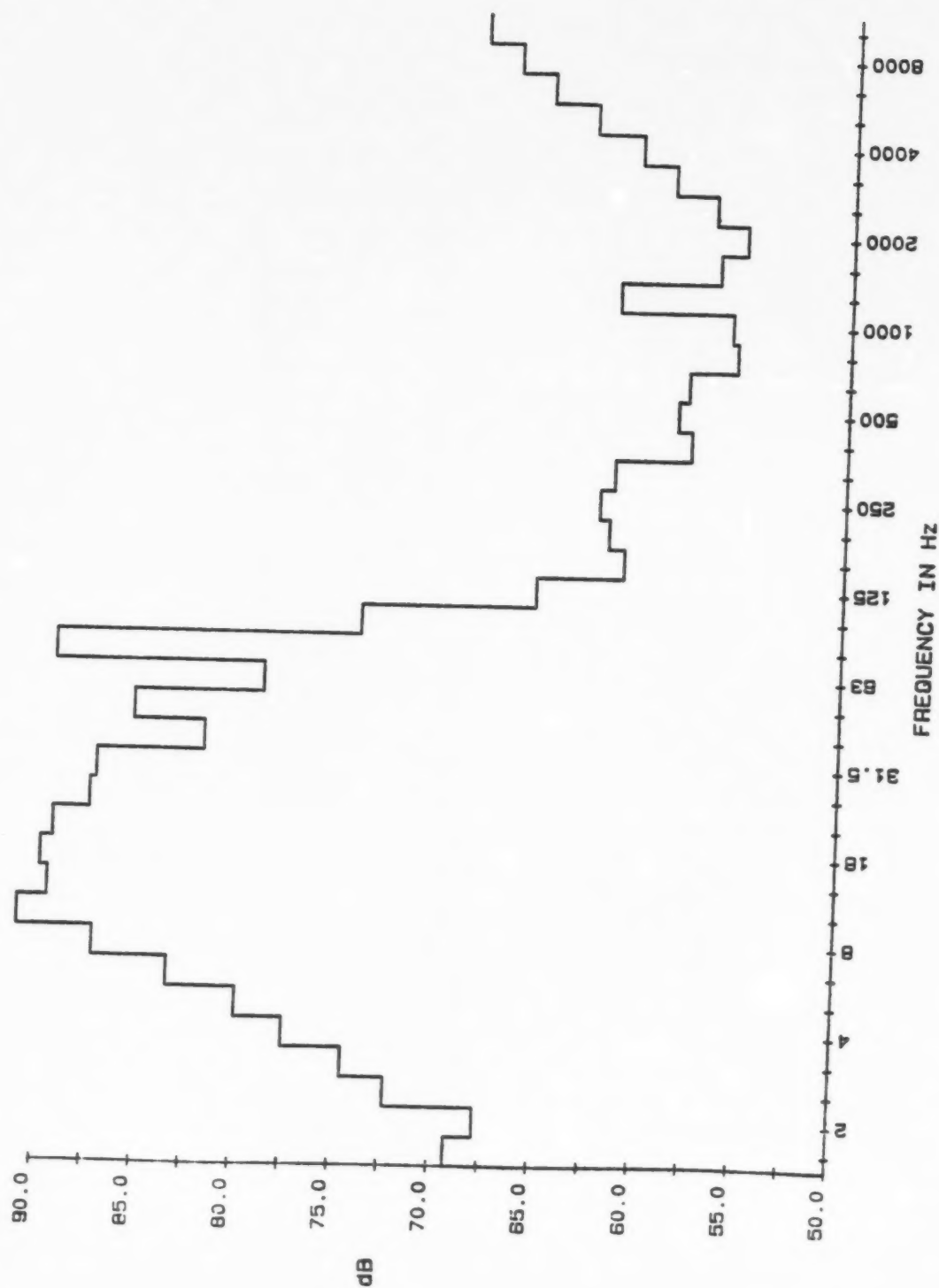


Fig. 5. Linear Sound Levels at Position 1 at a Speed of 60-75 km/hr

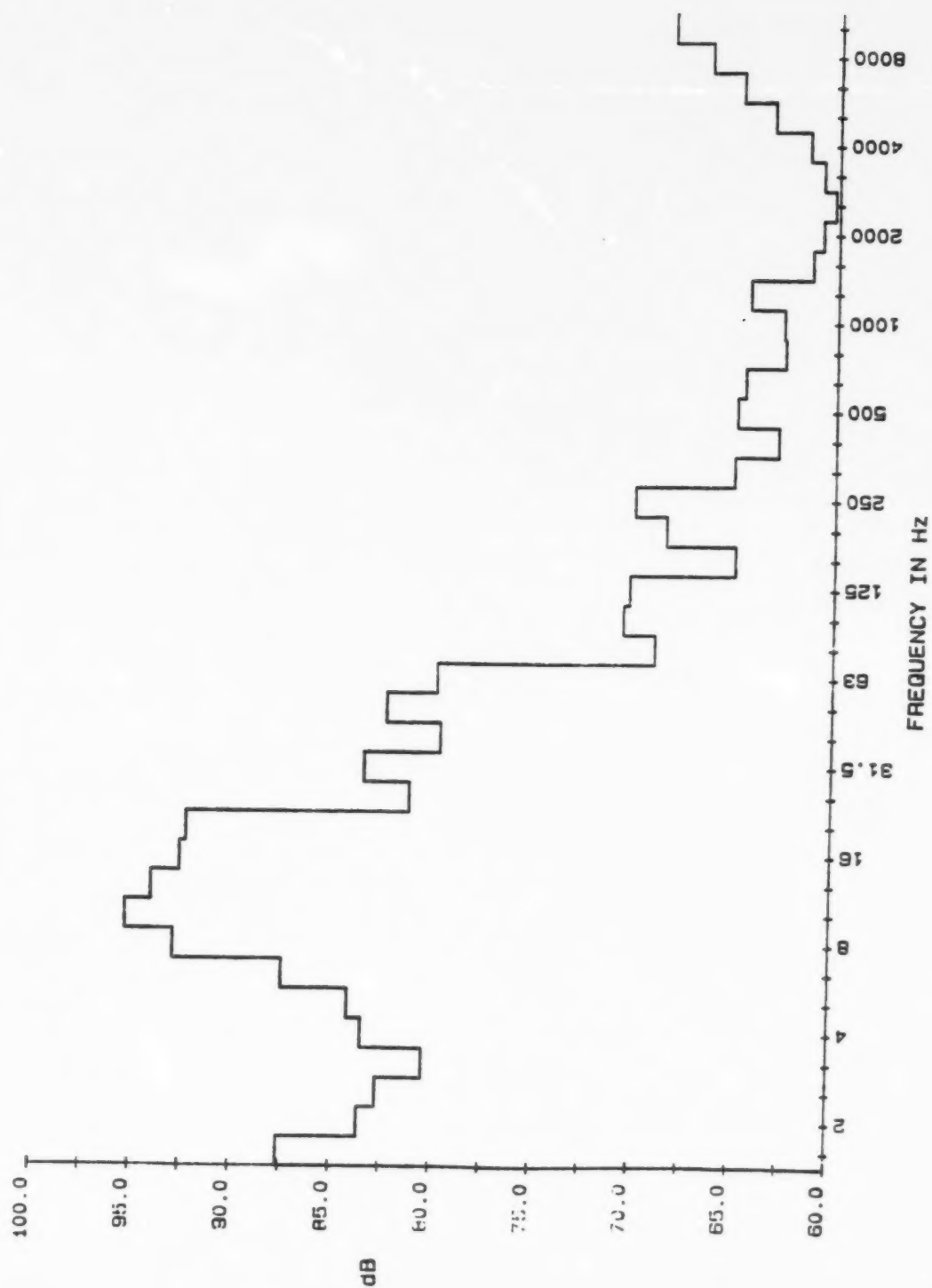


Fig. 6. Linear Sound Levels at Position 2 at a Speed of 60-75 km/hr

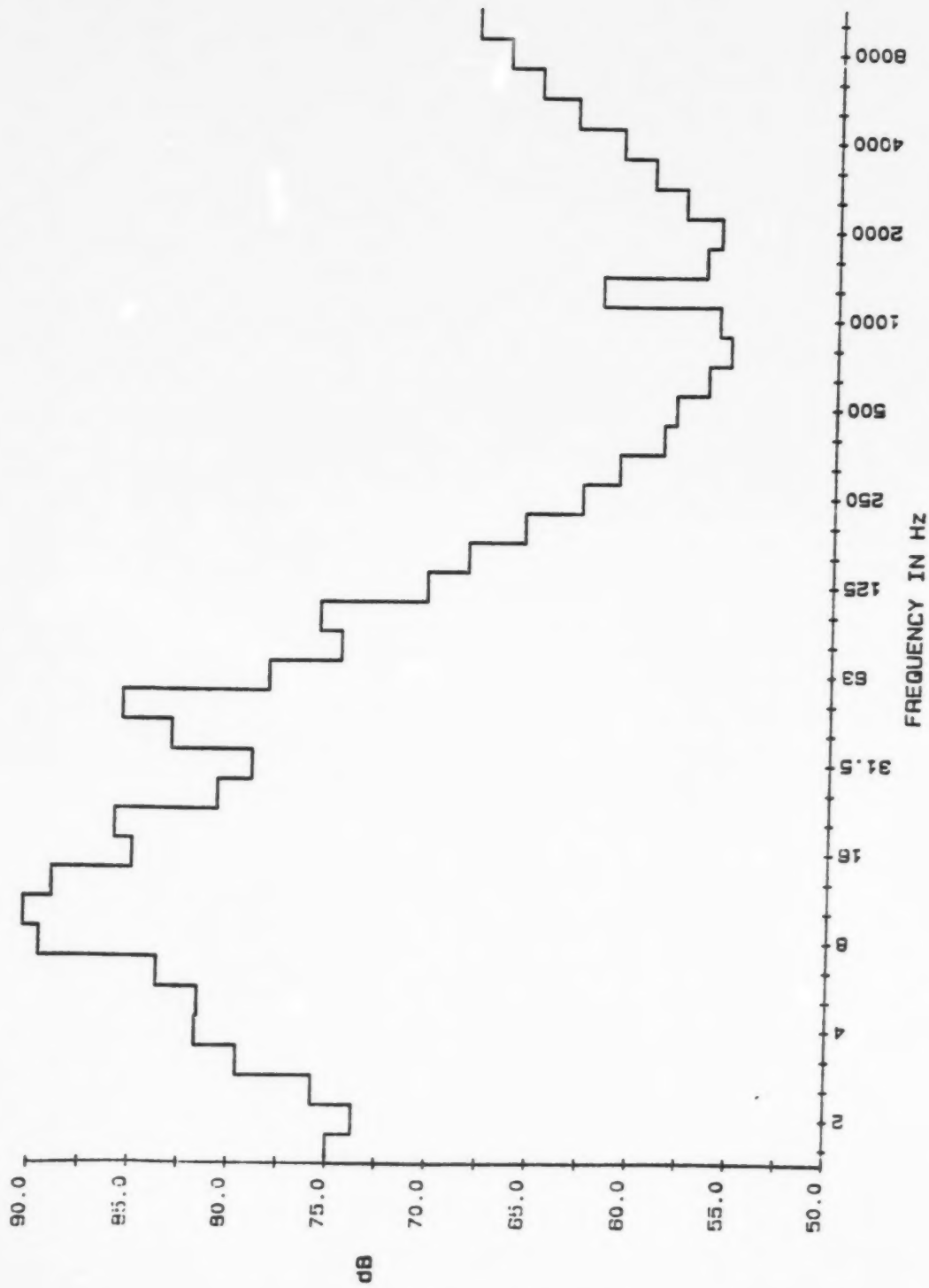


Fig. 7. Linear Sound Levels at Position 3 at a Speed of 60-75 km/hr

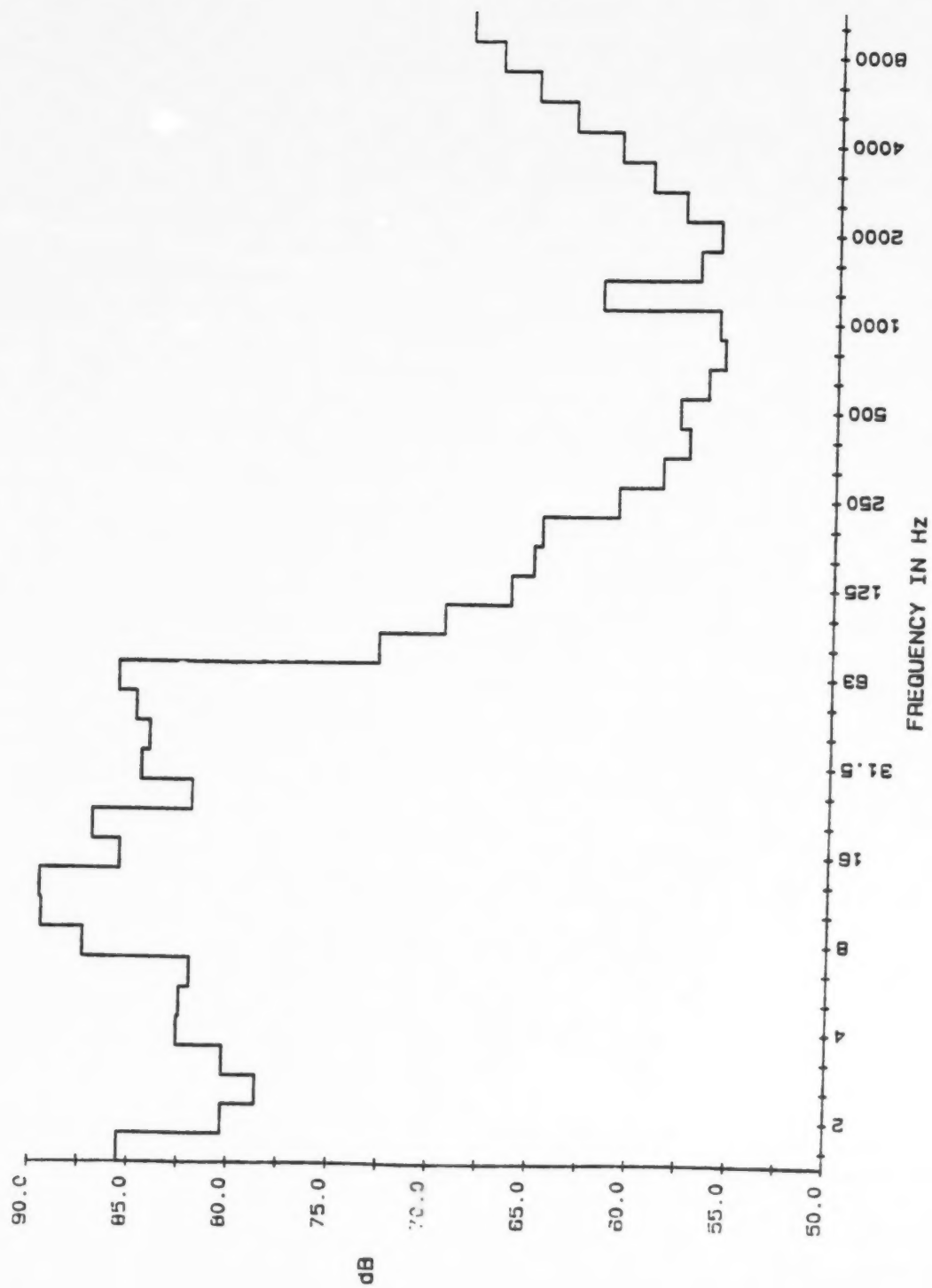


Fig. 8. Linear Sound Levels at Position 4 at a Speed of 60-75 km/hr

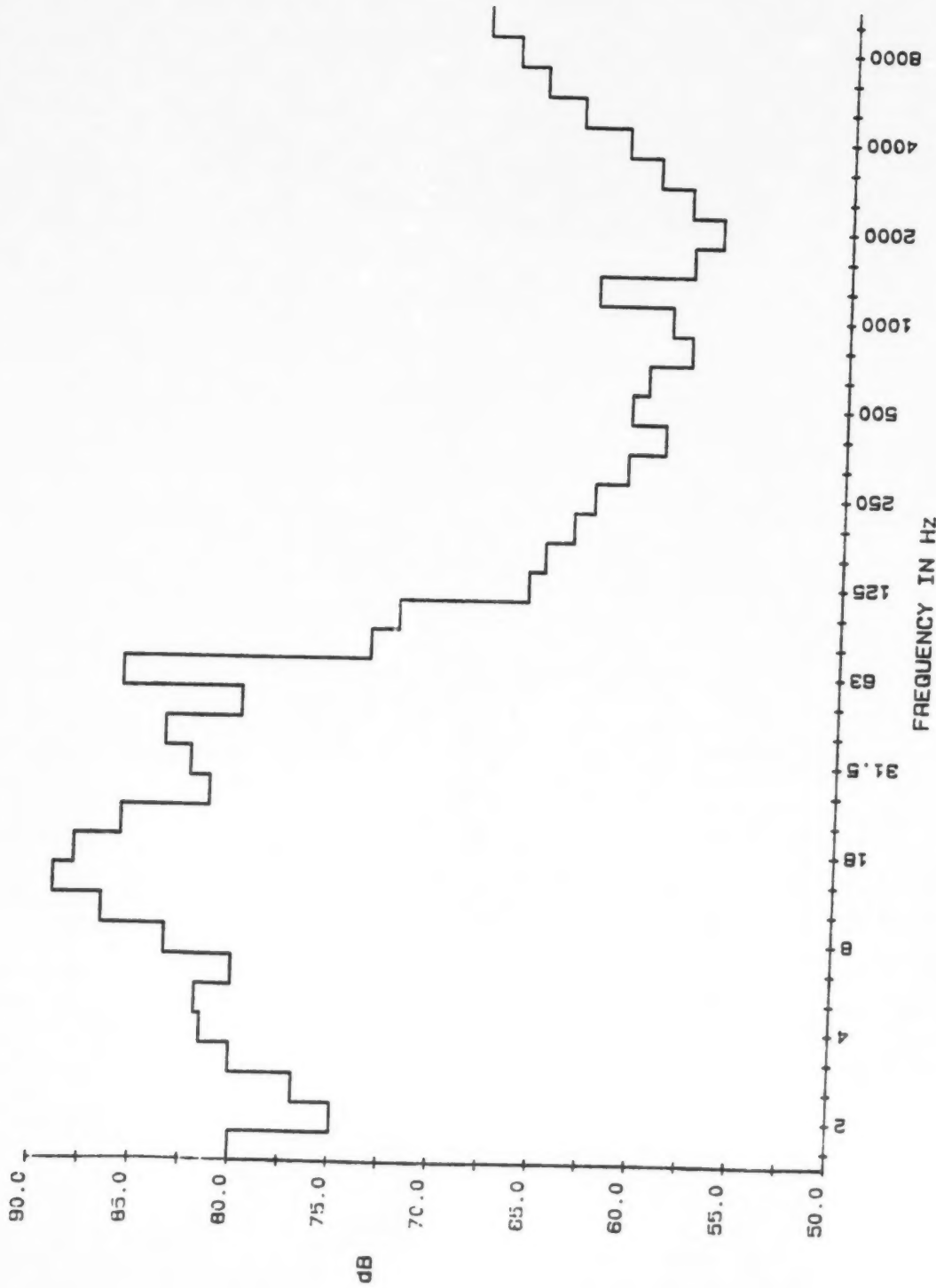


Fig. 9. Linear Sound Levels at Position 5 at a Speed of 60-75 km/hr

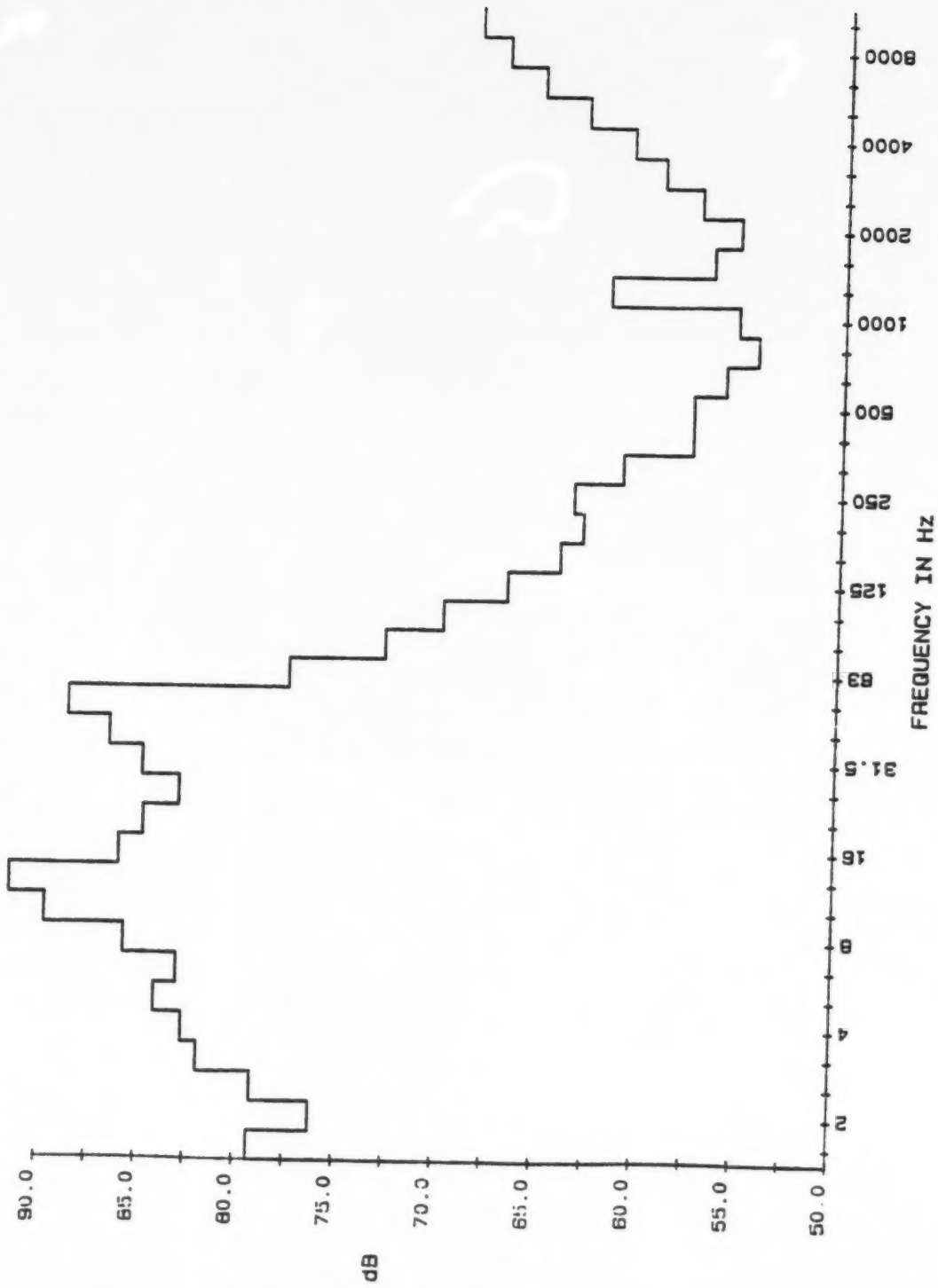


Fig. 10. Linear Sound Levels at Position 6 at a Speed of 60-75 km/hr

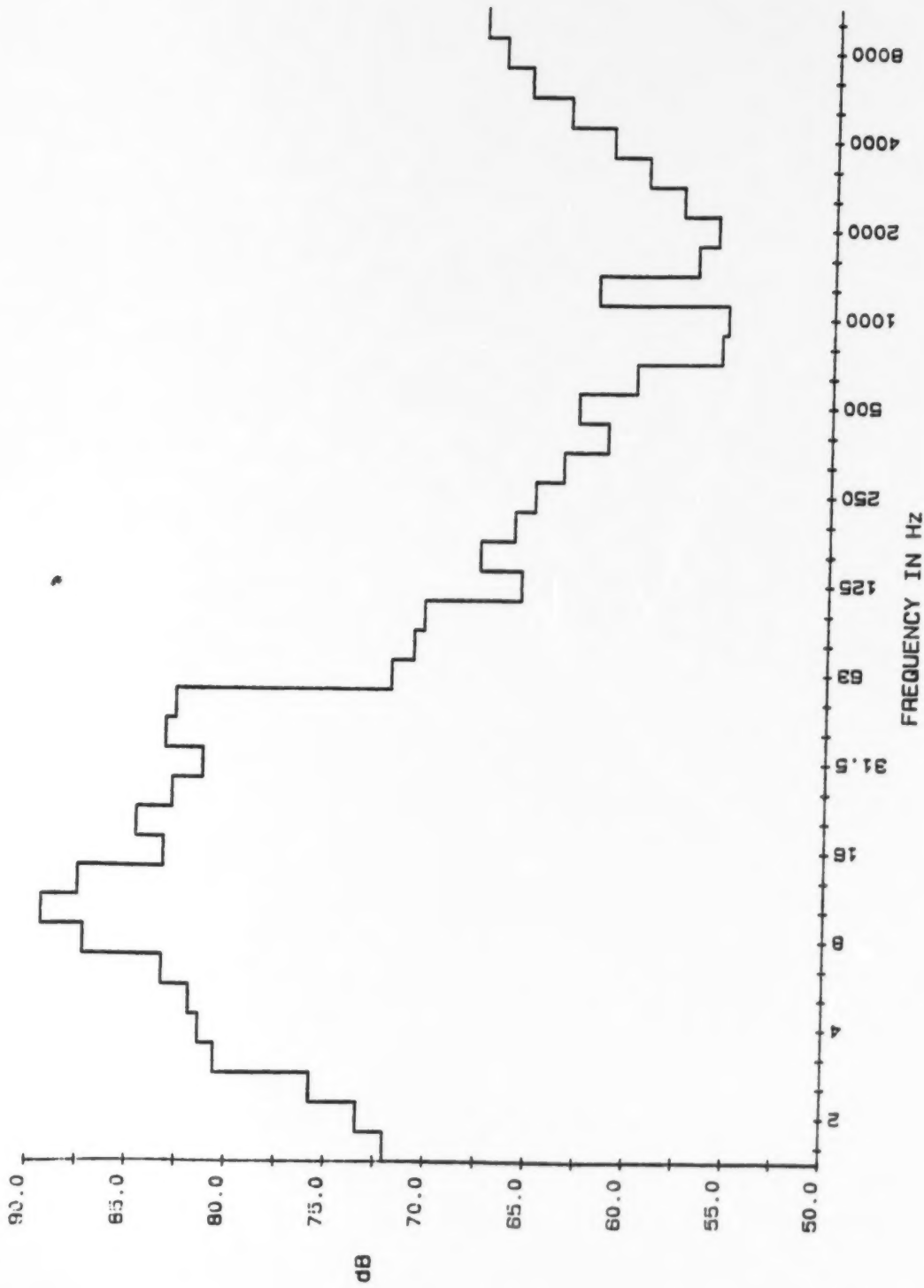


Fig. 11. Linear Sound Levels at Position 7 at a Speed of 60-75 km/hr

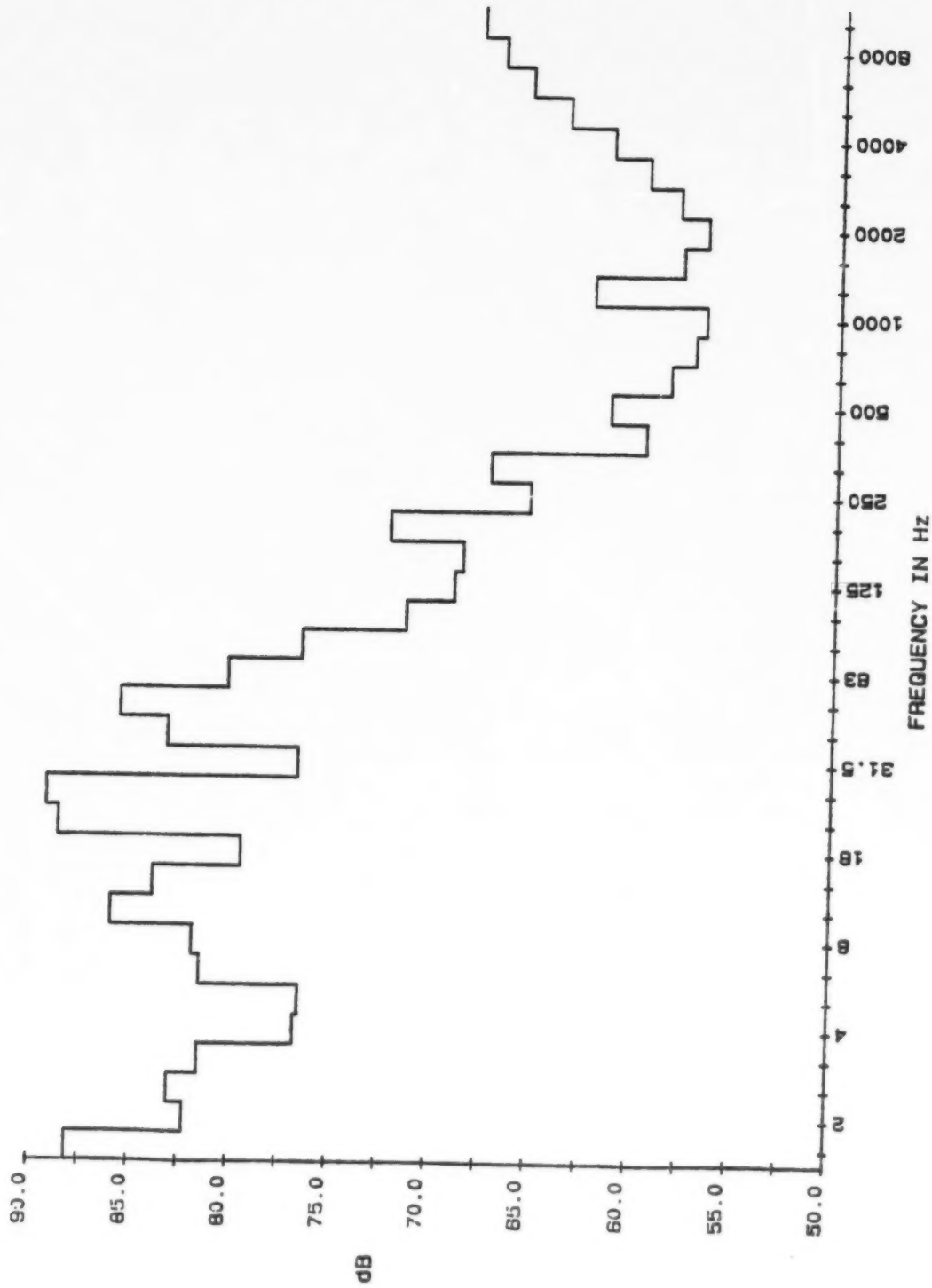


Fig. 12. Linear Sound Levels at Position 8 at a Speed of 45-50 km/hr

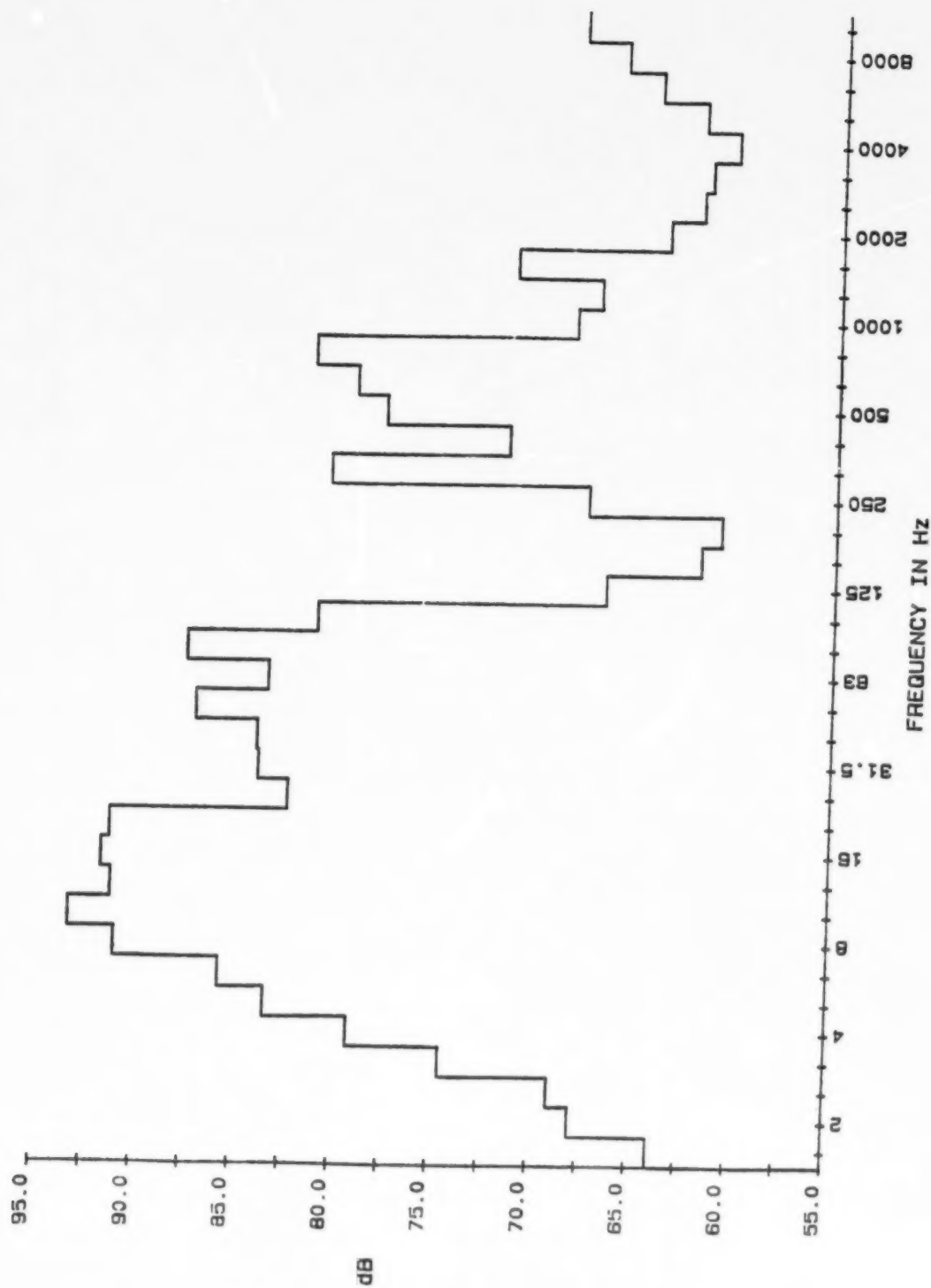


Fig. 13. Linear Sound Levels at Position 1 During Use of the External Air Horn

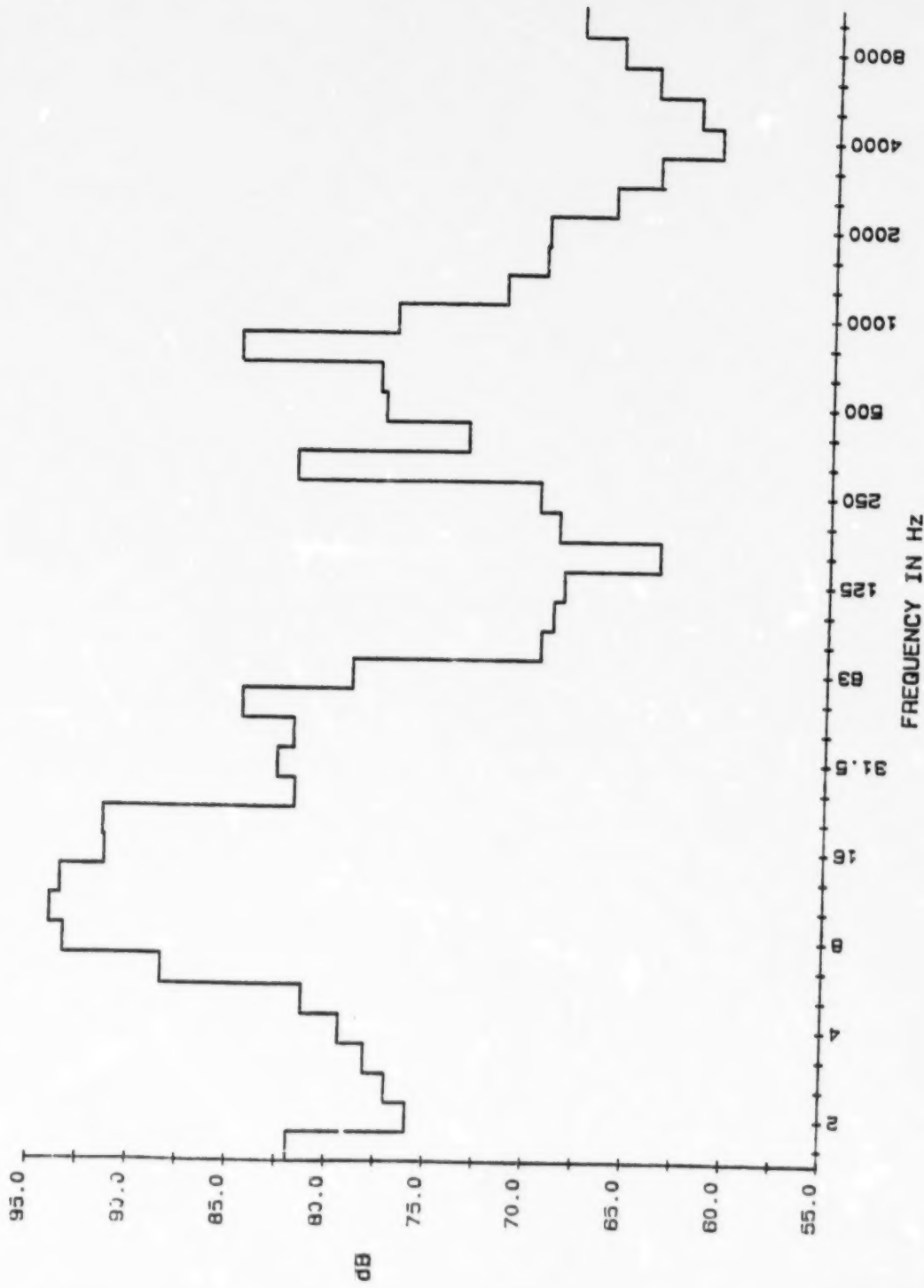


Fig. 14. Linear Sound Levels at Position 2 During Use of the External Air Horn

APPENDIX II

TEMPERATURE SURVEY

M. Krzyzanowski

The following temperature measurements were taken on the railbus BREL75. Due to the relatively mild outdoor temperatures encountered during testing, it was decided that only minimum heating would be required to heat the railbus. The roof mounted thermostat controlled heating system was used for this purpose. This system sends heated air through ducts in the roof area and vents it approximately 14 inches from the side walls and 84 inches from the floor along the interior length of the railbus. Also, floor heaters with heated engine coolant circulating in the heat exchangers provided some heat with no fan blowers running.

Conditions of Test

- 1) Test area was over 4 miles of track used also for ride quality tests (mileage 176 - 180 Lac St-Jean Sub.)
- 2) Engine was brought up to operating temperature.
- 3) Passenger compartment bulkhead doors were to be closed during temperature tests.
- 4) Test day was relatively mild winter temperatures, clear, sunny, little perceptible wind.
- 5) Solar radiation was felt strongly through railbus side windows by passengers (no tinting of glass).
- 6) Toilet and luggage side of railbus were on the shaded side of vehicle.

Note: Driver compartment temperatures were not taken because of the abundant heat available in these areas. The drivers would often have the compartment sliding window open to vent the cab.

Thermocouple Locations

Thermocouples were orientated so as not to receive direct radiation from heat or cooling sources.

Location

1. 78" from "B" end bulkhead
40" from floor
10" from wall
2. outside railbus attached to "A" end rearview mirror
3. 130" from "A" end bulkhead
7" from wall
5" from floor
4. 130" from "A" end bulkhead
12" from wall
40" from floor
5. 130" from "A" end bulkhead
31" from wall
65" from floor
6. 20' from "A" end bulkhead (at centre bulkhead location)
35" from wall
65" from floor
7. 45" from "B" end bulkhead
33" from wall
5" from floor
8. 42" from "B" end bulkhead
35" from wall
65" from floor
9. 23' from "A" end bulkhead (centre area between two adjacent seating areas)
10" from wall
5" from floor
10. 23' from "A" end bulkhead
10" from wall
40" from floor

Average Temperatures While Running at Speed

1) 30 mph "B" end leading

Pos.	1	2	3	4	5	6	7	8	9	10
°C	32.9	-7.4	21.8	25.9	26.9	36.7	23.8	29.0	23.8	30.4

2) 30 mph "A" end leading

°C 30.0 -7.9 23.3 26.7 28.1 36.2 23.9 26.3 24.1 29.0

3) 40 mph "B" end leading

°C 30.5 -6.4 23.6 26.9 28.2 35.8 24.4 28.2 24.9 30.4

4) 40 mph "A" end leading

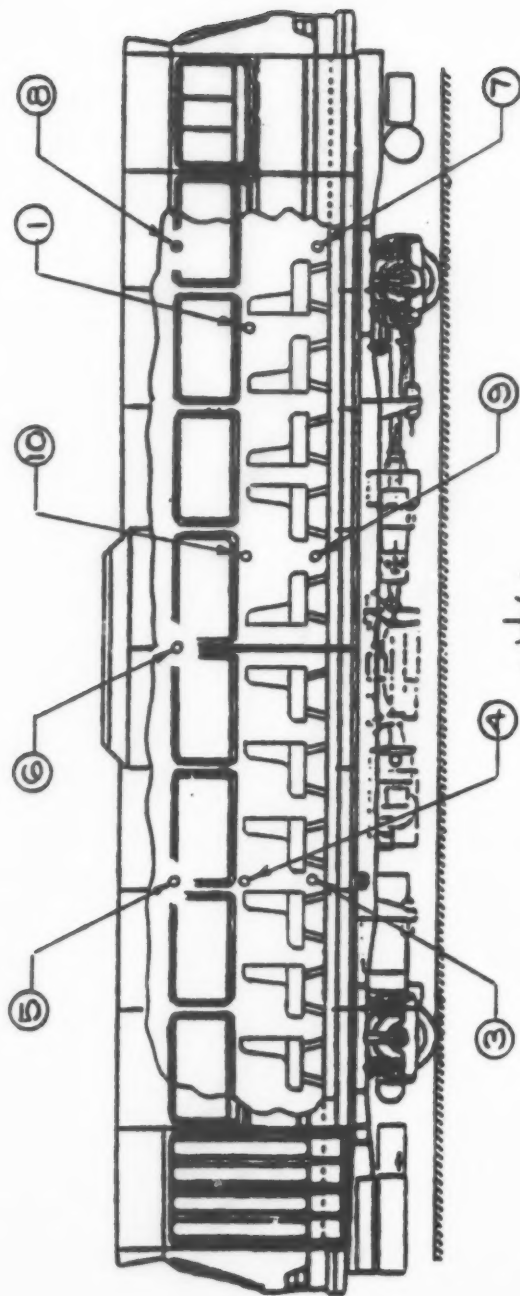
°C 27.2 -7.8 24.0 26.9 27.9 35.6 22.5 24.9 23.8 26.6

5) 50 mph "B" end leading

°C 29.0 -6.6 23.5 26.6 27.5 36.2 23.5 27.2 24.8 28.5

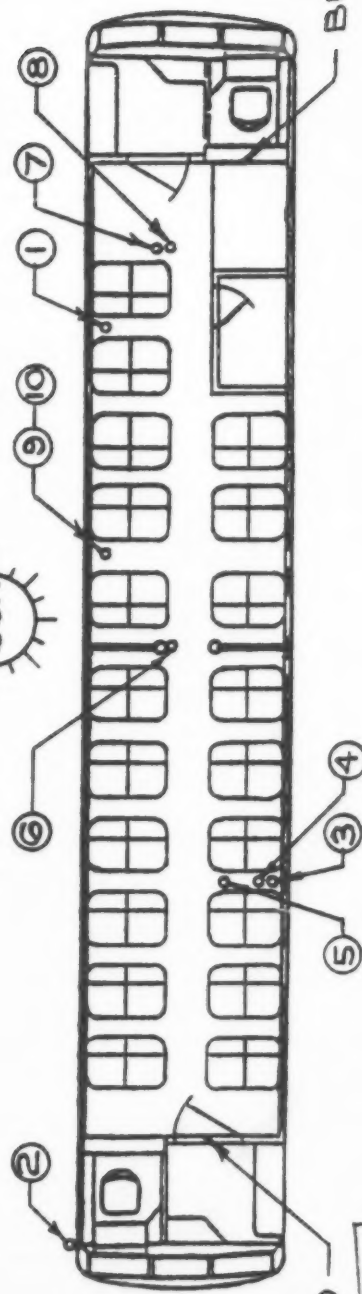
6) 50 mph "A" end leading

°C 27.8 -7.4 24.7 27.3 28.0 35.9 22.9 25.8 23.6 25.7



A END

B END



BULKHEAD

BULKHEAD

THERMOCOUPLE LOCATION BREL75

